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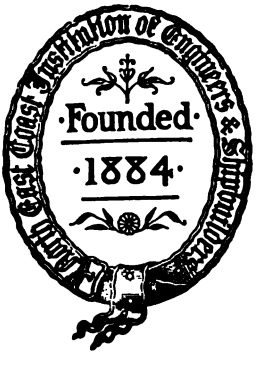

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VOLUME IV.

FOURTH SESSION, 1887-88.

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ERRATUM.

Omit the headline over table on page 231.—The evaporative trials with the boiler for Danish gunboat "Gronsund" are those referred to in the foot-note on page 227.

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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, Newcastle-upon-Tyne, *Vol.* XXXVI., *Part* 4.—Visit of the Mining Engineers to Newcastle-upon-Tyne and District. President's Address. Paper on the Mining Institutions of Great Britain.

Vol. XXXVII., *Part* 1.—A Further Attempt for the Correlation of the Coal-seams of the Carboniferous Formation of the North of England. The Pyrites Deposits of the Province of Huelva. Etc. *Part* 2.—Report of the Committee on Earth Tremors. On a Gauzeless Safety-Lamp. Description of a Miner's Safety-Lamp to meet the Requirements of the Mines new Regulation Act. The Endless Chain in Spain. *Part* 3.—Notes on the Tkiboulli Coal-fields (Caucasus). On an Improved Form of Seismoscope. Discussion on the Miner's Sun-light Electric Lamp. Borné Hand-Boring Machine. Miner's Safety-Lamp Cleaning Machine. Discussion the Coal-seams of the North of England. *Part* 4.—The Use of Iron Support the Main Roads of Mines. Coal Nodules from the Bore-hole Seam at Newca New South Wales. The Horizon of the Low Main Seam in a portion of the Durh Coal-field.

THE SOUTH WALES INSTITUTE OF ENGINEERS, Cardiff, *Vol.* XV., *No* Adjourned Discussion on the Mercier Safety-Lamp. Discussions upon the f ing:—Portable Electric Safety-Lamps. Poetsch's Freezing System of S through Quicksands. The Hazard Collieries, Belgium. Proposed Method tracting Gas from Fiery Seams. Shot Firing in Mines. Papers on Dampin in Mines. Harbours of Refuge in the Bristol Channel. *No.* 5.—Discuss Damping Dust in Mines. Adjourned Discussion on Portable Electric Lamps. Shot Firing in Mines (Part 2). Further Particulars of Poetsch's System of Sinking through Quicksand. Swan's Miner's Electric Safe Electric Pumping in Mines. Schanschieff's Portable Electric Lamps.

Discussion on Poetsch's Freezing System of Sinking through Quicksand. Discussion on Electric Pumping in Mines. Adjourned Discussion on Portable Electric Miners' Safety-Lamps. Shot Firing in Mines (Part 3).

THE UNITED STATES NAVAL INSTITUTION, Annapolis, Md., *Vol.* XIII., *No.* 3. —The Naval Brigade. Training of Enlisted Men of the Engineers' Force. Iron and Steel and the Mitis Process. A New Method for Carrying, Lowering, and Detaching Boats. Notes on the Literature of Explosives. Electric Motors. Etc. *No.* 4.—Discussion on the Naval Brigade. Infantry Fire Tactics. The V Gun Shield for Cruisers. The Separation of the Passage and Emergency Powers for War Ships. Notes on the Literature of Explosives. Aluminium Bronze for Heavy Guns. Etc. *Vol.* XIV., *No.* 1.—Annual Address, 1888. The Naval Uses of the Pneumatic Torpedo Gun. Notes on the Naval Brigade. The Resistance of Air to the Motion of Projectiles. Notes from the Journal of Lieutenant T. A. M. Craven. Notes on the Literature of Explosives. Our Naval Reserve and the Necessity for its Organisation. Aluminium Bronze for Heavy Guns. Etc. *No.* 2.—Notes from the Journal of Lieutenant T. A. M. Craven. A New Method of Reducing Chronometrical Longitudes. Three considered as a Tactical Unit. Velocities and Pressures in Guns. Ignition of Explosive Mixtures of Gases by Broken Incandescent Lamps. Etc.

BOOKS.

Engineering Popularly and Socially Considered. By J. W. C. Haldane.
Ship and Steamship Register of Bureau Veritas for 1887 and 1888 (2 volumes).
Spon's Engineers' Price Book.

PERIODICALS RECEIVED UP TO DATE.

Engineering, London, W.C.
Indian Engineering, Calcutta, British India.
Industries, Manchester.
Iron, London, E.C.
Marine Engineer, London.
Shipping World, London.
The Engineer, London, W.C.
The Iron and Coal Trades Review, London, W.C.
The Practical Engineer, Manchester.

LIST OF OFFICERS.

SESSION, 1887-8.

President:—W. THEO. DOXFORD.

Past-President:—W. BOYD.

Vice-Presidents:

Sir Benjamin C. Browne.	Wigham Richa
A. Cooth.	H. F. Swan.
J. Price.	Alex. Taylor.

Honorary Treasurer:—B. G. Nichol.

Councilmen:

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H. Charlton.	M. Sandison.
J. P. Hall.	W. G. Spence.
C. W. Hutchinson.	J. C. Stirzaker
W. Kilvington.	R. Thompson.
Arthur Laing.	J. Tweedy.
F. C. Marshall.	P. Watts.

R. L. Weighton.

Secretary and Treasurer:—J. Duckitt,

G, Exchange Buildings, King Street, Newcastle-upon-Ty

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1888.

EXPLANATION.

(A.)	Agent and Accountant.	(N. A.)	Naval Architect.
(C. E.)	Civil Engineer.	(R. M.)	Rope Manufacturer.
(E.)	Engineer and Boilermaker.	(S.)	Shipbuilder.
(F. M.)	Forge Master.	(S. O.)	Ship Owner.
(I. & S. M.)	Iron and Steel Merchants and Manufacturers.	(SUR.)	Engineer and Ship Surveyor.

HONORARY MEMBERS.

		ELECTED.
The Right Hon. Lord Armstrong, C.B., LL.D., F.R.S., Cragside, Rothbury		Nov. 1884
The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead		Nov. 1884
W. H. White, Esq., The Admiralty, Whitehall, London	(N A)	Nov. 1884

LIFE MEMBERS.

Fox, Samson, Messrs. The Leeds Forge Co., Leeds	(E)	Dec. 1887
Halley, David, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark...	(E)	Feb. 1887
Macoll, H., 2, Borough Road Terrace, Sunderland	(S)	Nov. 1884
Spence, W. G., 66, Elswick Road, Newcastle...	(E)	Nov. 1884

LIFE ASSOCIATE.

Eccles, Edward, G, Exchange Buildings, King Street, Newcastle...	(S O)	Oct. 1887

MEMBERS.

A.

Adamson, Alex., c/o Messrs. Barrow Shipbuilding Co., Barrow-in-Furness	(S)	Nov. 1885
Ahlbom, C., 11, Sidney Grove, Arthur's Hill, Newcastle-on-Tyne ...	(E)	Nov. 1884
Aitchison, Jas., Hylton, Sunderland	(S)	Nov. 1884
Alchin, A. H., 89, Wood Lane, Shepherd's Bush, London	(E)	Jan. 1885
Allan, Jas. McNeal, 5, Warwick Street, Heaton	(E)	Dec. 1886
Allan, T. J., The Green, Wallsend, Newcastle-on-Tyne	(N A)	Nov. 1884
Allardes, Wm., Greenville Terrace, Bloomfield, Belfast	(E)	Nov. 1884

ELECTED.

Anderson, A., Bright Street, Monkwearmouth, Sunderland ... Nov. 1884
Anderson, J., Messrs. Wigham Richardson & Co., Neptune Works, Low Walker ... ... Nov. 1884
Andrew, D., 31, Westmorland Road, Newcastle-on-Tyne ... ...(SUR) Jan. 1885
Andrews, Allan, Woodstock Street, Kilmarnock ... ... (E) Dec. 1885
Andrews, Jas., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) Nov. 1884
Anthony, Jas., 6, Northumberland Square, North Shields... ... (S) Oct. 1886
Armstrong, G. S., 12, Brookland Road, Hylton Road, Sunderland... Nov. 1884
Armstrong, Robert B., 47, Cromwell Street, Newcastle ... ... (E) Oct. 1887
Arnison, Geo., Jun., 5, Tavistock Place, Sunderland ... ...(N A) Nov. 1884
Ash, Mortimer W., 42, Percy Park, Tynemouth ... ... (E) Feb. 1887
Austin, S. P., Wear Dockyard, Sunderland ... ... (S) Nov. 1884

B.

Bailey, James, 6, Ashfield Terrace, Ryton-on-Tyne ... ... (E) Nov. 1884
Baird, Alex., 26, Brookland Road, Sunderland ... ... (E) Nov. 1884
Barley, C. J., Caterham Manor, Warlingham Station, Surrey ... ... (E) {Graduate, Feb. 1885 / Member, Dec. 1886
Bate, Edward R., 5, Ferndale Road, Clapham, London ... ... (E) Jan. 1885
Batey, John Thomas, 30, Richmond Street, Newcastle-on-Tyne ... (S) Nov. 1885
Baxter, J., 9, Warwick Street, Heaton, Newcastle-on-Tyne ... (E) Nov. 1884
Baxter, W. J., 2, E. Hamilton Terrace, Partick, Glasgow ... ... (E) Oct. 1886
Beadon, D. C., Messrs. R. & W Hawthorn, Leslie, & Co., St. Peter's (E) Jan. 1885
Bell, James, 29, Croft Terrace, Jarrow ... ... (E) Feb. 1887
Bergstrom, Gus., 14, St. Hilda Street, East Hartlepool ... ...(N A) Mar. 1886
Berkley, A. B., Grange Villa, Jarrow ... ... (E) Mar. 1887
Bindesböll, S. C. W., 1, Tamworth Road, Newcastle-on-Tyne ... (S) Nov. 1884
Bittleston, W. H., 9, Crooms Hill, Greenwich, S.E.... ... ... (S) May 1885
Black, Jas., Portobello Foundry, Sunderland ... ... (E) Jan. 1885
Black, Wm., Messrs. Black, Hawthorn, & Co., Gateshead ... ... (E) Jan. 1885
Blakston, J. W., 5, Douro Terrace, Monkwearmouth, Sunderland... (S) Jan. 1886
Blechynden, Alfred, 12, Cavendish Park, Barrow-in-Furness ... (E) Oct. 188
Blenkinsop, John N., Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 188
Blumer, Wm., Riversley, Milburn Terrace, Sunderland ... ... (S) Dec. 188
Bone, W. J., 61, Linskill Terrace, North Shields ... ... (S) Dec. 18
Boolds, Jas. H., Northumberland Shipyard, Howdon-on-Tyne ... (S) Oct. 1
Borovski, G., Baltic Works, St. Petersburg, Russia ... ... (E) Oct.
Boyd, Wm., North House, Long Benton ... ... (E) Nov.
Bramwell, Balfour, 2, Beverley Terrace, Cullercoats (E) {Graduate, Nov. / Member, Nov.
Brankston, R. T., 37, Hawthorn Street, Newcastle-on-Tyne ... (E) Nov.
Bray, C. H., 6, Kent Street, Jarrow ... ... (E) Mar
Bremberg, G., Messrs. Kockum's Mekaniska, Verkestad, Malmo, Sweden ... ... (S) Nov.
Brock, John, 5, St. Mary's Place, Newcastle-on-Tyne ... ... (E) Nov.
Brough, Robert, 9, Western Hill, Sunderland ... ... (E) Dec

ELECTED.

Brown, Eugene, 28, Alexandra Place, Newcastle-on-Tyne... ... (E) Feb. 1886
Brown, T. R., 34, Dock Street East, Sunderland ... (E) {Graduate, May 1885 / Member, Oct. 1886
Brown, William, 22, Hayburn Crescent, Partick, Glasgow ... (E) April 1887
Browne, Sir B. C., West Acres, Benwell, near Newcastle-on-Tyne (C E) Jan. 1885
Buchanan, A., Messrs. Barrow Shipbuilding Co., Barrow-in-Furness (S) Nov. 1884
Buckland, H. B., Walker Boiler Works, Low Walker ... ... (E) Nov. 1885
Buglass, A. W. ... ... Nov. 1884
Bulmer, John, 1, Graingerville North, Newcastle-on-Tyne ... (E) Mar. 1886
Burdon, J. G., 20, Archbold Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Burns, J., 8, Kaisor Terrace, West Hartlepool ... ... Nov. 1884
Butterfield, George, 30, John Candlish Road, Millfield, Sunderland Nov. 1884

C.

Campbell, Hartley, Sunderland Engine Works, South Docks, Sunderland ... ... (E) Nov. 1884
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Carnegie, Alexander, 65, Gloucester Road, Newcastle-on-Tyne .. (S) Nov. 1884
Carr, J. W., Point Pleasant House, Wallsend ... ... (E) Feb. 1885
Carr, Thomas R., Baltic Chambers, Sunderland ... ... (E) Feb. 1887
Carrick, H., Holly House, Gateshead ... ... (E) Nov. 1884
Carrick, Henry H., Holly House, Gateshead ... ... (E) Nov. 1885
Carstons, Samuel, 3, Hope Street, Stockton-on-Tees ... ... (S) Dec. 1887
Carter, G. J., Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Dec. 1886
Carter, Thos., 7, Dundas Street, Monkwearmouth, Sunderland ... (E) Nov. 1884
Cay, Arthur, Westoe, South Shields ... ... (E) Nov. 1884
Chapman, Capt., Belle Vue, Low Fell, Gateshead ... ... (E) Nov. 1884
Chapman, Hedley, 147, Park Road, Newcastle-on-Tyne ... ... (E) Feb. 1886
Charlton, Henry, Messrs. Hawks, Crawshay, & Sons, Gateshead ... (E) Nov. 1884
Charlton, R. B., Jun., Manors Railway Station Works, Newcastle... (E) Nov. 1884
Charlton, T., 25, Lincoln Street, Gateshead ... ... (E) Nov. 1884
Christie, C. A., 4, Colbeck Terrace, Tynemouth ... ... (E) Nov. 1884
Christie, C. J. D., Neptune Works, Low Walker ... ... (S) Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth ... ... (S) Nov. 1884
Clark, Geo., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884
Clark, George, Jun., Southwick Engine Works, Sunderland ... (E) Feb. 1888
Clark, Henry, Southwick Engine Works, Sunderland ... ... (E) Oct. 1887
Clarke, Thos., Elswick Marine Engine Works, Newcastle-on-Tyne (E) Nov. 1884
Clarke, William, Victoria Engine Works, Gateshead ... ... (E) Oct. 1887
Conning, Alfred C., Dunston Iron and Steel Works, Gateshead ... (F M) May 1885
Conràdi, Carl, Bergens mech Verksted, Bergen, Norway ... ... (E) Nov. 1884
Cooper, William, Baltic Chambers, Quayside, Newcastle-on-Tyne (E) Feb. 1888
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn (S) Nov. 1884
Crawford, Jas., 9, Custom House Court, Quayside, Newcastle ...(SUR) Nov. 1886
Crawford, W. A. F., 2, Diamond Street East, Pembroke Dock, Wales ... ... (E) Nov. 1884
Cross, Wm., 4, Fenham Terrace, Newcastle-on-Tyne ... ... (E) Mar. 1886

ELECTED.

Cruddas, W. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick ... ... (E) Dec. 1884
Cuevel, John L., Kadyk, Amsterdam ... ... (E) Mar. 1886
Cummins, W. R., Neptune Engine Works, Low Walker ... ... (E) Nov. 1884
Curwen, Henry R., Maschinenban Actien Gesselschaft Vulcan Bredow, Stettin, Germany ... ... (S) Graduate, Feb. 1886 / Member, Oct. 1887

D.

Dacres, T. H., 14, De Grey Street, Newcastle ... ... (E) Mar. 1887
Dalrymple, Wm., Messrs. Hawks, Crawshay, & Sons, Gateshead ... (E) Dec. 1886
Darling, W. J., Lloyd's Surveyor, Leith ... ... (S) April 1887
Darney, John, Messrs. Short Bros., Pallion, Sunderland ... ... (S) Nov. 1884
Davie, Albert, c/o Messrs. Hutcheson & Co., Rowand Road, Dumbarton, N.B. ... ... (E) Graduate, Feb. 1886 / Member, Oct. 1887
Davis, F. B., 11, Sydenham Terrace, Newcastle-on-Tyne ... ... (S) Jan. 1885
Davison, John, 4, Dean Terrace West, Southwick, Sunderland ... (E) Nov. 1884
Davison, John W., The Crescent, Low Fell, Gateshead ... ... (E) Nov. 1886
Dempsy, S., Messrs. Wallsend Slipway and Engineering Co., Wallsend ... ... (S) Nov. 1884
Derby, J. W., 48, South Cumberland Street, Glasgow ... ... (E) Nov. 1884
Dick, Francis, Elmwood Terrace, Field Road, Forest Gate, London, E. ... ... (E). Nov 1885
Dickinson, F. T., Park House, Sunderland ... ... (E) Graduate, May 1885 / Member, Oct. 1886
Dickinson, James, Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, John, Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, W., Park House, Sunderland ... ... (E) Nov. 1884
Dixon-Brown, L. D., Unthank Hall, Haltwhistle ... ... (S) Nov. 1886
Dixon, Raylton, Cleveland Shipyard, Middlesbrough ... ... (S) Feb. 1888
Donald, James, 48, St. Luke's Terrace, Pallion, Sunderland ... (S) Nov. 1884
Donovan, J. W., 4, Elizabeth Street, Newcastle Road, Sunderland (E) April 1885
Douglas, John F., Messrs. Wigham Richardson & Co., Low Walker ... ... (E) Jan. 1888
Douie, Andrew ... ... (S) Nov. 1887
Down, T. B., 24, George's Road, Elswick, Newcastle-on-Tyne ... (E) Nov. 1884
Dowsen, Chas., 8, Croft Terrace, Jarrow ... ... (E) Dec. 1885
Doxford, Charles, D., Bainbridge Holme, Tunstall Road, Sunderland ... ... (S) Nov. 1884
Doxford, R. P., Pallion Engine Works, Sunderland ... ... (E) Nov. 1884
Doxford, W. T., Pallion Shipyard, Sunderland ... ... (S) Nov. 1884
Drakenberg, J. A. ... ... (E) Feb. 1886
Duckitt, Jno., Exchange Buildings, King Street, Newcastle ... (E) Nov. 1884
Dudgeon, F. S., 112, Fenchurch Street, London, E.C. ... ... (E) Feb. 1885
Dugdale, W. H., Messrs. Workman, Clark, & Co., Spencer Basin, Belfast, Ireland ... ... (E) Dec. 1886
Dunlop, William, 31, Hartington Street, Barrow-in-Furness ... (E) Mar. 1888
Dykes, James, 78, Dilston Road, Newcastle-on-Tyne ... ... (E) May 1885

ELECTED.

E.

Eckmann, John, Sunderland Engine Works, South Docks, Sunderland ... ... (E) May 1885
Edmiston, Jas. B., Ivy Cottage, Highfield Road, Walton, Liverpool (E) Nov. 1886
Elliott, Consitt, 4, Suffolk Street, Sunderland ... ... (E) May 1885
Engelbach, Herbert R., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works ... ... (E) Nov. 1884
Errington, Joseph R., c/o Mr. Bell, Contractor, Market Weighton, Yorkshire ... ... (E) Jan. 1888
Eshelby, William, 4, Lax Terrace, Stockton-on-Tees ... ... (E) Feb. 1888
Evans, Henry A., 16, Windsor Terrace, Gateshead ... ... (E) Mar. 1887
Evers, G., Actiengesellschaft Wesu, Bremen, Germany ... ... (S) Nov. 1884

F.

Fairman, A. E., 23, St. Bede's Terrace, Sunderland... ... ... (N A) Oct. 1886
Fairweather, C. W., Ernest Scott & Co., Close, Newcastle ... ... (E) Dec. 1886
Farina, A. J., Oakwood House, Westmorland Road, Newcastle ... (E) Nov. 1884
Fenwick, James, 9, Park Road, South Shields ... ... (E) Mar. 1888
Fleming, Charles Edward, 71, Elswick Road, Newcastle-on-Tyne... (E) Nov. 1884
Fletcher, James, 74, Old Dumbarton Road, Glasgow ... ... (E) Dec. 1885
Fletcher, Robert, Walker Forge, Low Walker ... ... (F M) Dec. 1886
Flohr, Justus, 32, Birkencellies, Stettin, Germany ... ... (E) Oct. 1886
Foley, Nelson, Villa Beatrice, Parco Griffeo, Naples, Italy ... (E) Nov. 1884
Forbes, John ... ... (E) Oct. 1885
Foster, G. E., 23, Holly Street, Jarrow ... ... (E) Jan. 1886
Foster, Henry, Newburn Steel Works, Newburn ... ... (E) April 1885
Fothergill, J. R., 1, Bathgate Terrace, West Hartlepool ... ... (E) Mar. 1886
Fownes, Henry, Tyne Forge, Ouseburn, Newcastle ... ... (F M) Nov. 1884
Franki, J. P., Messrs. Morts Dry Dock & Engineering Co., Sydney, N.S.W., Australia ... ... (E) Jan. 1886
Furneaux, J. B., Victoria Engine Works, Gateshead ... ... (E) Nov. 1885
Furness, John, 24, Falconar Street, Newcastle-on-Tyne ... ... (E) Nov. 1885
Furse, Fred., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) April 1887

G.

Gad, Oscar, 27, Western Hill, Sunderland ... ... (S) April 1885
Gannaway, H. G., 17, Caroline Street, Jarrow ... ... (S) Nov. 1884
Garratt, H. A., c/o Mrs. Henderson, Long Benton, Newcastle-on-Tyne ... ... (E) { Graduate, Nov. 1884 / Member, Nov. 1886
Garrett, G. H., Messrs. R. Stephenson & Co., South Street, Newcastle ... ... (E) Oct. 1886
Gibson, H., 16, Stansfield Street, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, W. F., 7, South Western Terrace, Nicholstown Southampton Nov. 1884
Gibson. W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884
Gilroy, Thomas R., Messrs. Laird Bros., Shipbuilders, Birkenhead (E) Nov. 1886
Glencross, Thos., 11, Rychill, Newcastle-on-Tyne ... ... (E) Feb. 1885
Glover, Terrot, 6, Azalea Terrace, Sunderland ... ... (E) Mar. 1886

ELECTED.

Gordon, William James, 74, Old Dumbarton Road, Glasgow ... (E) Oct. 1887
Graham, Edwin, Messrs. Osborne, Graham, & Co., Hylton, Sunderland ... ... (S) Nov. 1884
Graham, Joseph, 32, Brookland Road, Sunderland ... ... Nov. 1884
Graham, Wm., Dean Crescent, Low Walker-on-Tyne ... ... (S) Nov. 1884
Gravell, John, Custom House Court, Quay, Newcastle-on-Tyne ...(SUR) Nov. 1884
Gray, George, 13, Harold Street, Sunderland ... ... (E) Feb. 1888
Gray, Harry, 43, Grove Street, Newcastle-on-Tyne ... ... (E) Dec. 1885
Green, W. G., Messrs. Palmer's Iron and Shipbuilding Co., Jarrow (E) Nov. 1884
Green, William, Messrs. Barrow Shipbuilding Co., Barrow-in-Furness ... ... (E) Oct. 1885
Greener, G. W., 110, George's Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Grey, James ... ... Nov. 1884
Grieves, Robert, 38, Linskill Terrace, North Shields (S) { Graduate, Nov. 1884 / Member, Dec. 1886
Gulston, A., Clayton Park Lodge, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1884

H.

Hall, Edward, 8, Grange Road West, Jarrow ... ... (S) Nov. 1885
Hall, J. Percy, Mayfield Villa, Jarrow ... ... (E) Oct. 1885
Hall, John W., Abden Shipyard, Kinghorn, N.B. ... ... (S) Oct. 1887
Hamilton, John, 81, Charlotte Street, Carlisle ... ... (E) Nov. 1886
Hamilton, R. B., Rose Cottage, Willington Quay ... ... (E) Nov. 1884
Hansen, F. T., 3, Villa Place, Union Lane, Gateshead ... ... (E) Nov. 1884
Harding, J. C., 9, Alderson Street, West Hartlepool ... ... (E) Nov. 1884
Hardy, Arthur Francis, Germania Werft, Gaarden bei Kiel, Germany ... ... (S) Oct. 1887
Harkness, Richard, Stephenson Street, Willington Quay ... ... (S) Nov. 1884
Harlow, F., 40, Clarence Crescent, Newcastle-on-Tyne ... ... Nov. 1884
Harman, Bruce, 10, Hamilton Terrace West, Partick, Glasgow ... (E) Oct. 1886
Harper, J. H., 1, Beaumont Street, North Shields ... ... (E) Jan. 1885
Harrold, Alexander, 19, Lawton Street, Newcastle-on-Tyne ... (E) Nov. 1884
Hartness, J., East Boldon, near Sunderland ... ... (E) Nov. 1884
Havelock, Michael, Commercial Chambers, Side, Newcastle-on-Tyne (E) Dec. 1887
Haver, Arthur H., 15, Howarth Street South, Hylton Road, Sunderland ... ... (S) Nov. 1884
Head, Archibald P., 20, Elswick Row, Newcastle ... (E) { Graduate, Nov. 1884 / Member, Oct. 1887
Headlam, Robert, 5, Edward Street, Stockton-on-Tees ... ... (E) Nov. 1886
Heck, John H., Lloyd's Registry, Aberdeen, N.B. ... ... (S) Nov. 1885
Helyer, A. J., Germania Werft, Gaarden bei Kiel, Germany ... (S) Oct. 1887
Henderson, George, 54, Westmorland Road, Newcastle-on-Tyne ... (E) Nov. 1884
Henderson, G. B., 23, Holmside, Sunderland... ... ... (E) Nov. 1884
Henderson, Robert, 11, Hadrian Road, Wallsend ... ... (S) Nov. 1884
Hepburn, Alex., Grosvenor Place, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1885
Hepple, William, Slipway, North Shields ... ... (E & S) Oct. 1885
Hildrey, A. J., 11, Chester Street, Sunderland ... ... (S) Nov. 1884

ELECTED.

Hill, Maxwell, Messrs. Palmer's Iron and Shipbuilding Co., Jarrow (S) Nov. 1884
Hill, Maxwell, Stettiner Maschinenban Actien Gesellschaft, Vulcan Bredow, Stettin, Germany .. .. (S) Nov. 1887
Hindhaugh, C. W., 59, Bedford Street, North Shields ... ... (S) Nov. 1884
Hindson, William, 3, Claremont Park, Gateshead ... ... (E) Nov. 1884
Hirst, Richard, 4, Cleveland Road, North Shields ... ... (E) Nov. 1885
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Holmes, John H., Portland Road, Newcastle-on-Tyne ... ... (E) Jan. 1888
Homji, A. C. N., Gordon Mills, Byculla Flats, Bombay, India ... (E) Nov. 1884
Hooper, Ernest, 5, John Candlish Road, Millfield, Sunderland ... (E) Nov. 1885
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend... (S) Nov. 1884
Hunter, J. W., 9, Alice Street, Sunderland ... ... (E) May 1885
Hunter, Summers, Rosehill Terrace, Howdon-on-Tyne ... ... (E) Nov. 1885
Hunter, Wm. Gallon, Grange Road, West Hartlepool ... ... (S) Dec. 1885
Hutchinson, C. W., 52, Westmorland Road, Newcastle-on-Tyne ... (E) Nov. 1884
Huxham, J. L., 183, Albert Road, Jarrow ... ... (S) Nov. 1884
Hymers, Richard, 197, Norfolk Road, Byker ... ... (E) Mar. 1887

I.

Inglis, John, Messrs. Ramage & Ferguson, Leith ... ... (S) April 1887
Inglis, John, Jun., Pointhouse Shipyard, Partick, Glasgow ... (E) Oct. 1886
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884
Irwin, Thomas F., 2, Tower Chambers, Old Churchyard, Liverpool ... ... (C E & N A) Mar. 1888

J.

Jackson, Vincent, 19, Regent Street, Hartlepool ... ... (S) April 1888
James, M. C., Messrs. Robert Stephenson & Co., Ld., Engineers and Shipbuilders, Hebburn ... ... (S) Nov. 1884
Jamieson, John, Regent Street, Hartlepool ... ... (E) Nov. 1885
Jobling, J. C., 1, Brandling Place West, Newcastle-on-Tyne .. (E) Nov. 1884
Jobling, W. J., Queen Street, Newcastle-on-Tyne ... ... (E & S O) Nov. 1884
Johnson, John, 80, Dock Street East, Sunderland ... ... (S) May 1885
Johnson, T. Allan, 56, Harrison Street, Barrow-in-Furness ... (S) Nov. 1884
Johnstone, William, 7, Hamilton Terrace West, Partick, Glasgow, N.B. ... ...(SUR) Nov. 1884
Jones, Morlais G., 4, Windsor Terrace, Chester Road, Old Trafford, Manchester ... ... (E) Nov. 1887

K.

Kean, James ... ... (E) Nov. 1884
Keene, H. R., 120. Park Road, Newcastle ... ... (E) { Graduate, May 1885 / Member, April 1887
Kellner, T., 116, Rychill, Newcastle-on-Tyne ... ... (N A) Oct. 1887
Key, Alexander, Mersey Chambers, Liverpool ... ...(SUR) Nov. 1884
Kilvington, W., Northumberland Engine Works, Wallsend ... (E) Nov. 1884
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885

ELECTED.

L.

Laidley, R. W., Messrs. Mort & Co., 155, Fenchurch St., London, E.C. (E) April 1887
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 1884
Laing, Jas., Jun., Deptford Yard, Sunderland ... ... (S) Nov. 1884
Laing, John, Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) Nov. 1884
Larkin, James, East Jarrow ... ... (E) Nov. 1884
Leddicoat, Frederick, 5, Cromwell Terrace, Gateshead ... ... (E) Oct. 1885
Lewis, Henry W., Llwynynhess, Abercanaid, near Merthyr, Glamorganshire, Wales ... ... (E) Nov. 1885
Lewis, R. A., Newburn Steel Works, Newburn ... ... (E) Nov. 1884
Liddell, A. R., 10, Hartington Street, Barrow-in-Furness ... ... (S) Nov. 1884
Liddell, J., Messrs. Denny & Co., Engine Works, Dumbarton ... (E) Nov. 1884
Lindfors, H., P.O. Box, 752, Norwalk Comm., U.S. America ... (S) Oct. 1886
Littleboy, Chas. Wm., 12, Shaftesbury Street, Stockton-on-Tees ... (S) Oct. 1887
Livingston, Thos., 4, St. John's Terrace, Jarrow ... ... (S) Nov. 1884
Livingstone, John, 25, Grove Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Lohmeyer, H., 27, Choppington Street, Elswick, Newcastle ... (E) Nov. 1884
Long, A. E., 124, Albert Road, Jarrow ... ... (S) Nov. 1884
Lynn, J., St. Luke's Engine Works, Sunderland ... ... (E) Nov. 1884

M.

Macarthy, Harry, Ashfield House, Newcastle ... ... (E) Nov. 1888
MacBoy, John, 18, Linskill Terrace, North Shields ... ... (E) Feb. 1886
Mace, W., 253, Albert Road, Jarrow ... ... (E) Jan. 1886
MacGregor, John, 51, Harrison Street, Barrow-in-Furness ... (E) Mar. 1888
MacHaffie, John, 38, South Hawk Street, Albany, New York, U.S. America ... ... (E) Dec. 1885
Macoll, D. C., 14, Connaught Terrace, Jarrow ... ... (S) Nov. 1884
Manuel, G. W., Fern Bank, Catford Hill, London ... ... (E) Dec. 1885
Marlborough, Richard, 18, Elgin Street, Sunderland ... ... (S) Nov. 1884
Marr, James, 6, Ash Place, Sunderland ... ... (S) Nov. 1884
Marshall, F. C., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) Nov. 1884
Marshall, R. J., 32, Mariners' Cottages, South Shields ... ... (E) Mar. 1887
Martens, D., 52, Kent Street, Jarrow ... ... (E) Mar. 1887
Mastaglio, W. D., 15, Rosslyn Terrace, Sunderland ... ... (E) Nov. 1885
Matthews, A., The Baths, Blyth ... ... (E) Nov. 1884
Matthews, Jas., Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle ... ... (E) Oct. 1886
Maughan, Wm., 15, Addison Road, Heaton ... ... (E) Mar. 1887
McGlashan, Arch., 26, Milton Street, West Hartlepool ... ... (S) Nov. 1885
McIlvenna, J. G., Messrs. The Tyne Pontoon and Dry Docks Co., Wallsend ... ... (S) Nov. 1884
McIntyre, John, 3, Abbotsford Terrace, Newcastle-on-Tyne ... (S O) Jan. 1885
McKay, Jno., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) Nov. 1884
Menzies, Wm., The Side, Newcastle-on-Tyne ... ... (E) Nov. 1884
Messenger, Thomas, 2, Clarence Lawn, Dover, Kent ... ... (E) Mar. 1887

ELECTED.

Metcalf, J. C., 22, St. Vincent Street, Sunderland ... ... (SUR) Nov. 1884
Metcalfe, C. S., 5, Tunstall Terrace West, Sunderland ... ... (E) Nov. 1884
Milburn, Christopher J., 102, Tynemouth Road, Heaton, Newcastle (E) Feb. 1888
Millar, Thos., Messrs. Sir W. G. Armstrong, Mitchell & Co., Walker Shipyard, Low Walker ... ... (S) Nov. 1884
Mills, John, 18, Belvedere Street, Heaton, Newcastle-on-Tyne ... (E) Feb. 1888
Milne, W. J., 19, Fisher Street, Walker ... ... (S) Nov. 1884
Milton, J. T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) Nov. 1886
Mitchell, Chas., Jesmond Towers, Newcastle-on-Tyne ... ... (S) Nov. 1884
Moffat, D., 86, Falconar Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885
Moody, Thomas V., c/o Messrs. Ernest Scott & Co., Close, Newcastle-on-Tyne ... ... (E) Dec. 1887
Morgan, W. H., 141, Denmark Street, Heaton, Newcastle-on-Tyne (E) Nov. 1884
Morison, D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885
Mörk, Peter, 3, Hawthorn Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886
Mowat, John, 3, Cooper Street, Monkwearmouth, Sunderland ... (S) Nov. 1884
Mudd, Thomas, Central Marine Engine Works, West Hartlepool (E) Mar. 1886
Muir, J. M., Messrs. Wigham Richardson & Co., Low Walker ... Nov. 1884
Muir, Robert, 17, Westmorland Road, Newcastle ... ... (SUR) Oct. 1886
Myles, David, Neptune Engine Works, Low Walker ... ... (E) Nov. 1884

N.

Nance, A. J. ... ... (E) April 1887
Napier, W. E., 129, Park Road, Newcastle ... ... (E) Nov. 1884
Newitt, Leonard, Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne ... ... (E) Dec. 1887
Newton, W. A., 90, Broughton Road, South Shields (E) { Graduate, May 1885 / Member, Oct. 1886
Nichol, B. G., 49, Leazes Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Nichol, Thos., 50, Ripon Street, Monkwearmouth, Sunderland (SUR) Nov. 1884
Nicol, John M., 10, Linskill Place, North Shields ... ... (E) Nov. 1884
Nicolson, J. T., Mrs. Wightman, 85, Marchmont Road, Edinburgh (E) Nov. 1884
Niven, William A., 38, Mast Street, Barrow-in-Furness ... ... (E) Nov. 1887
Norman, W. S., Messrs. Tyne Pontoon and Dry Docks Co., Low Walker ... ... (E) Nov. 1884
Noton, F. R., 32, Azalea Terrace, Sunderland ... ... (S) Nov. 1884

O.

O'Neil, J. J., 2, Erith Terrace, Pallion, Sunderland ... ... (E) Nov. 1884
Orde, E. L., Orde House, Morpeth ... ... (E) Oct. 1887
Oxley, G., Station Road, Howdon ... ... Nov. 1884

P.

Pacey, John W., 64, Hotspur Street, Heaton... ... ... (E) Feb. 1888
Panton, W. H., Stockton Forge, Stockton-on-Tees ... ... (E) Nov. 1887

ELECTED.

Parkin, Rd., Messrs. Donkin & Nichol, St. Andrew's Works, Gallowgate, Newcastle ... ... (E) Nov. 1884
Parsons, Hon. Charles A., Elvaston Hall, Ryton-on-Tyne ... ... (E) Dec. 1887
Patterson, Jas., The Green, Wallsend ... ... (E) Nov. 1884
Pattison, Jos., 2, Church Terrace, Wallsend ... ... (E) Nov. 1884
Paulson, John, 85, Tynemouth Road, Heaton, Newcastle ... ... (S) Feb. 1886
Pearson, James John, 22, Milton Street, Newcastle-on-Tyne ... (E) Feb. 1886
Penny, A. W., 69, Percy Road, Whitley ... ... (S) Nov. 1884
Penny, R. H., 15, Azalea Terrace South, Sunderland ... ... (S) Nov. 1884
Perrett, J. Richard, 14, Eskdale Terrace, Jesmond ... ... (N A) Oct. 1887
Petree, James, Messrs. Laird Bros., Birkenhead ... ... (S) Oct. 1885
Phillips, Walter, 3, West Grove Terrace, Greenwich, London ... (E) Oct. 1886
Phillipson, Roland, Tynemouth ... ... (E) Dec. 1884
Phorson, P., 86, Roker Avenue, Sunderland ... ... (S) Nov. 1884
Pickering, Thos., 25, Ford Street, Sunderland ... ... Nov. 1884
Pilcher, F. J., 3, City Buildings, Old Hall Street, Liverpool ... (S) April 1887
Pilling, J., 11, Rosslyn Terrace, Chester Road, Sunderland ... Nov. 1884
Plotnicki, E. C., 10, West Percy Street, North Shields ... ... (E) Nov. 1886
Potts, John George, 8, Gladstone Street, Sunderland ... ... (E) Nov. 1884
Potts, T. T. ... ... (E) Jan. 1886
Prest, Stanley Faber, Chatsworth Terrace, Barrow-in-Furness ... (E) Mar. 1888
Price, John, 6, Osborne Villas, Jesmond, Newcastle-on-Tyne ... (S) Nov. 1884
Prince, Alfred, Kent Villa, Jarrow ... ... (E) Nov. 1884
Pryor, Benjamin, 20, Lawton Street, Newcastle-on-Tyne ... ... Nov. 1885
Purdy, A. J. ... ... Nov. 1884
Purvis, John, 1, Broughton Road, South Shields ... ... (E) Dec. 1886
Putnam, T., Darlington Forge, Darlington ... ... (F M) Nov. 1884
Putnam, William, Darlington Forge, Darlington ... ... (F M) Nov. 1884

R.

Rae, John, 4, Grey Street, Glasgow, N.B. ... ... (E) April 1886
Ralston, G. C., 82, Tamworth Road, Newcastle ... ... (E) Oct. 1887
Ramage, J. T., The Hawthorns, Leith, N.B. ... ... (E) April 1887
Ramsay, C. W., Hornsbory, Lgungby, Sweden ... ... Nov. 1884
Ramsay, W. G., 10, Stanhope Road, Tyne Dock ... ... (E) Mar. 1887
Rankine, Jno., 21, Payne Street, North Shields ... ... (E) Nov. 1884
Readhead, Jas., Argyle Terrace, South Shields ... ... (S) Nov. 1884
Readhead, John, Jun., 18, Thomas Street, South Shields ... ... (E) Mar. 1886
Readhead, R., Beach View, South Shields ... ... (E) Nov. 1884
Readhead, W. B., Beach View, South Shields ... ... (S) Nov. 1886
Reavell, W., 18, North View, Heaton ... ... (E) {Graduate, April 1885 / Member, Oct. 1887}
Reed, J. W., 96, Queen's Road, Bootle, Liverpool ... ... (E) Nov. 1884
Reed, T. A., 1, St. John's Terrace, Jarrow ... ... (C E) Mar. 1887
Rendal, L. J., 61, Westmorland Road, Newcastle-on-Tyne ... ... (E) Mar. 1887
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields ... (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886

ELECTED.

Reynolds, Edward, Messrs. Vickers, Sons & Co., Sheffield ... ... (E) Jan. 1888
Reynolds, W. G., 7, St. Thomas' Square, Newcastle-on-Tyne ... (E) Oct. 1886
Richardson, J. Wigham, Neptune Works, Low Walker ... ... (S) Nov. 1884
Richardson, T., Jun., Hartlepool Engine Works, Hartlepool ... (E) April 1888
Rickaby, A. A., Bloomfield Engine Works, Sunderland ... ... (E)
Ridley, J. C., Swalwell Steel Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's... (E) Nov. 1884
Ritson, M., 3, Mowbray Terrace, Sunderland ... ... (E) Nov. 1884
Robinson, B. A., 5, The Knoll, Sunderland ... ... (E) Nov. 1884
Robinson, William, 6, Choppington Street, Newcastle-on-Tyne ... ... (E) Graduate, May 1885; Member, April 1888
Robson, Arthur, Messrs. J. Blumer & Co., Sunderland ... ... (S) Dec. 1886
Robson, John H., 4, Camilla Street, Gateshead ... ... (E) Nov. 1885
Robson, J. M., c/o W. Whyte, B, Lombard Street, Newcastle ... (E) Nov. 1884
Robson, M., 19, Zion Terrace, Newcastle Road, Sunderland ... (S) Nov. 1884
Robson, Thos., Copperas Works, Low Walker ... ... (S) Nov. 1886
Ropner, Robert, Jun., Preston Hall, Stockton-on-Tees ... ... (S) Feb. 1886
Rowan, Jas., 231, Elliott Street, Glasgow ... ... (E) Nov. 1886
Rowell, G. W., 22, Durham Street, Newcastle-on-Tyne ... ... (E) Feb. 1885
Rowell, H., Jesmond Gardens, Newcastle-on-Tyne ... ... Nov. 1884
Roylance, E. H., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne (E) Dec. 1886
Rusden, L., 11, Mistletoe Road, Jesmond, Newcastle-on-Tyne ... (E) Nov. 1884
Rutherford, G., Messrs. Wallsend Slipway Co., Engine Works, Cardiff ... ... (S) Oct. 1886
Rutherford, T. A., c/o Messrs. Harland & Wolff, Belfast ... ... (S) Nov. 1884
Ruthven, M. W., c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne ... ... (S) Dec. 1887
Ryder, C. L., 58, Fern Avenue, Newcastle-on-Tyne... ... ... (E) Oct. 1886

S.

Salmon, P., St. Bede's Park, Sunderland ... ... (SUR) Nov. 1884
Sanderson, J., 31, Park Road, Jarrow ... ... (S) Nov. 1884
Sandison, M., 34, Park Road, Newcastle-on-Tyne ... ... (E) Dec. 1884
Sawyers, John, Messrs. Thos. Wilson, Sons, & Co., Hull ... ... (E) Oct. 1886
Schaeffer, A. G., 4, Benton Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scorer, G. S., Messrs. T. & W. Smith, North Shields ... ... (S) Jan. 1885
Scotson, Alf., Messrs. Blyth Shipbuilding Co., Blyth ... ... (S) Feb. 1887
Scotson, Wm., 66, Osgathorpe Road, Sheffield ... ... (E) Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scott, H., 47, Mainsforth Terrace, Sunderland ... (E) Graduate, May 1886; Member, April 1888
Scott, Joseph R., 9, Queen Street, Newcastle ... ... (E) Oct. 1887
Scott, Wm., 5, Osborne Terrace, Newcastle-on-Tyne ... ... Nov. 1884
Seabury, Edward, 40, West India Road, Limehouse, London, E. ... (E) Mar. 1886
Sells, C., c/o Messrs. Gio Ansaldo, Sampierdarena, Genoa, Italy ... (E) Oct. 1887
Shand, H., 41, Grosvenor Place, West Jesmond, Newcastle ... (E) Nov. 1884
Sharer, E., Shipyard, Pallion, Sunderland ... ... (S) Oct. 1886

		ELECTED.
Sharp, A. E., Albert Terrace, Jarrow	(E)	Nov. 1884
Shaw, Jas., 24, Blyth Terrace, Gateshead	(E)	Jan. 1885
Sheppard, W. O., c/o J. H. Wheeler, Esq., Daylesford, Victoria, Australia	(E)	Mar. 1887
Shevill, W. H., 5, Avenue Terrace, Sunderland		Nov. 1884
Shiells, Jas., 22, Tunstall Vale, Sunderland	(E)	Graduate, May 1885 Member, Oct. 1886
Shilston, Thomas, 14, Wentworth Place, Newcastle-on-Tyne	(SUR)	Nov. 1885
Short, J. Y., 49, West Sunniside, Sunderland	(S)	Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland	(S)	Nov. 1884
Shotten, John W., 51, Falmouth Street, Newcastle ...	(SUR)	Nov. 1886
Sinclair, R., c/o J. R. C. Sinclair, Esq., 2, West Quay, Greenock ...	(E)	Nov. 1884
Sinton, John K., 7, Grasmere Terrace, Gateshead	(E)	Nov. 1885
Sisterson, G. R., Locomotive Department, London and South Western Railway, Nine Elms, London, S.W....	(E)	Nov. 1884
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool	(S)	Nov. 1886
Sjögren, H., Kockum's Mekaniska, Verkstad, Malmo, Sweden ...	(S)	Nov. 1884
Smith, Charles Mayfield, 29, Mitchell Street, West Hartlepool ...	(S)	April 1888
Smith, Eustace, 5, Queen Street, Newcastle-on-Tyne	(S)	Nov. 1884
Smith, J.		Nov. 1884
Smith, R. J., 2, West Lawn, Sunderland	(E)	Nov. 1884
Smith, Reginald Thomas, 77, Park Road, Newcastle-on-Tyne ...	(E)	April 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-on-Tyne	(E)	April 1885
Smith, Wm., 51, Dock Street East, Sunderland	(E)	Nov. 1884
Soliani, Nabor, Connitato Pei Designa delle Navi Ministero dilla Marina, Roma, Italy	(S)	Jan. 1885
Soulsby, J. C., 4, Bute Crescent, Cardiff	(SUR)	Nov. 1886
Spear, John, Messrs. T. Wilson & Sons, Hull...	(E)	Oct. 1887
Spencer, John C., Walbottle Hall, near Newcastle-on-Tyne	(I & S M)	Dec. 1885
Spencer, J. W., Newburn Steel Works, Newburn	(E)	Feb. 1885
Spencer, R. E. E.	(E)	Nov. 1884
Spiers, James		Nov. 1884
Stafford, William, Dunston-on-Tyne	(E)	Nov. 1885
Stephenson, C., 5, West View, Wallsend	(S)	Nov. 1884
Stevenson, R.	(E)	Graduate, Mar. 1886 Member, Oct. 1886
Stevenson, Wm., 25, Argyle Place, Partick, Glasgow	(E)	Nov. 1884
Stirling, Andrew, Jun., 2, Greenvale Terrace, Dumbarton ...	(E)	Feb. 1888
Stirzaker, J. C., 86, Brighton Grove, Newcastle	(E)	Nov. 1884
Stokoe, Thomas, 4, Lower Archer Street, West Hartlepool ...	(S)	Dec. 1885
Stone, Wm., 13, Rosslyn Terrace, Sunderland		Nov. 1884
Stubbings, James, Cornhill, Sunderland	(E)	Nov. 1884
Surtees, A. W., Frame, Low Teams, Gateshead	(E)	Oct. 1887
Surtees, R., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's	(E)	Nov. 1884
Sutton, James, 68, Park Road, Newcastle-on-Tyne	(S)	Jan. 1885

ELECTED.

Sutton, Jos., 68, Park Road, Newcastle-on-Tyne ... (E) {Graduate, Mar. 1886 / Member, Oct. 1886

Swainston, Wm., Rokeby Street, St. Mary's Road, Sunderland ... (E) Nov. 1884

Swan, H. F., North Jesmond, Newcastle-on-Tyne ... ... (S) Nov. 1884

Swan, Thomas, 152, Ellison Street, Jarrow ... ... Nov. 1884

Swinburne, T. M., Bewick Road, Gateshead ... ... (E) Jan. 1885

Swinburne, M. W., 117, Park Road, Newcastle-upon-Tyne ... (E) Mar. 1886

T.

Tate, Chas. H., 7, Side, Newcastle-on-Tyne ... ... (N A) Nov. 1884

Tatham, Stanley, Messrs. Hawks, Crawshay, & Sons, Gateshead ... (E) Feb. 1887

Taylor, Alexander, Mercantile Chambers, Quayside, Newcastle-on-Tyne ... ... (E) Nov. 1884

Taylor, C. W., Messrs. Thornewill & Warham, Burton-on-Trent ... (E) April 1885

Taylor, J. E., 13, Exchange, Plymouth .. ..(SUR) Nov. 1884

Taylor, Tom Henry, 17, Meldon Terrace, Heaton, Newcastle ... (E) Oct. 1885

Thompson, C. E., Messrs. J. L. Thompson & Sons, Sunderland ... (S) Nov. 1884

Thompson, Charles, 9, Dean Street, Newcastle-on-Tyne ... ... (E) Feb. 1887

Thompson, Jas., 11, Elmwood Street, Sunderland ... ... (E) Dec. 1886

Thompson, John, Post Office Chambers, Newcastle-on-Tyne ... (E) Nov. 1884

Thompson, J. E., Thornhill Park, Sunderland ... ... (S) Nov. 1884

Thompson, J. L., Jun., North Sands Shipyard, Sunderland ... (S) Nov. 1884

Thompson, Nicol, 32, Lawton Street, Newcastle-on-Tyne ... ... (S) Nov. 1884

Thompson, Robert, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884

Thompson, R. C., Bridge Dockyard, Sunderland ... ... (S) Nov. 1884

Thorn, W. H., 5, Waterville Terrace, North Shields ... ... (E) Nov. 1884

Tinn, Fred. D., 5, Hawthorn Terrace, South Shields ... ... (S) Nov. 1886

Tocher, Joseph W., Wallsend-on-Tyne ... ... (S) Oct. 1887

Todd, Surtees, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn ... ... (S) Nov. 1884

Todd, Thomas, 20, Billiter Street, London, E.C. ... ... (E) Nov. 1885

Tone, John M. F., 50, Clayton Park Square, Newcastle (E) {Graduate, April 1885 / Member, Oct. 1887

Toomer, C. R., 26, North View, Heaton, Newcastle ... (E) {Graduate, May 1885 / Member, Feb. 1887

Trewent, F. J., 9, Northumberland Terrace, Tynemouth ... ... (S) Dec. 1884

Tritton, S. B., Assistant Locomotive Superintendent, Eastern Bengal State Railway, Kanchrapara, Calcutta, India ... (E) Nov. 1884

Turnbull, T. W. H., 17, Monk Street, Monkwearmouth, Sunderland ... ... (E) Nov. 1884

Turner, Henry John, 11, Tindal Street, Westgate Road, Newcastle-on-Tyne ... ... (E) Feb. 1888

Turner, S. J., 86, Addison Road, Heaton ... ... (E) Mar. 1887

Tweddell, R. H., 14, Delahay Street, Westminster, London, S.W. ... ... (E) Jan. 1885

Tweedy, J., Neptune Works, Low Walker ... ... (E) Nov. 1884

Tyzack, George, Dean Street, South Shields ... ... (E) April 1888

ELECTED.

U.

Ullstrom, Otto, Messrs. Raylton Dixon & Co., Cleveland Dockyard, Middlesbro', or 110, Grange Road East, Middlesbro' ... ... (S) Nov. 1884

Ulm, John, Marine Casino, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *via* Galeazzo Alessi 6 into 1, Genoa, Italy ... ... (E) Dec. 1885

W.

Wailes, E. F., 35, Close, or 13, Tankerville Terrace, Newcastle-on-Tyne ... ...(SUR) Nov. 1884

Wailes, T. W., Mount Stuart Dry Docks, Cardiff ... ... (E & S) Oct. 1887

Walker, Archibald, 147, Constitution Street, Leith, N.B. ... ... (E) April 1887

Wallau, J., Messrs. Black, Hawthorn, & Co., Gateshead ... ... (E) Nov. 1884

Walliker, J. F., 6, Lovaine Terrace, North Shields ... ... (E) Nov. 1885

Walton, F. W., 24, Lord Street, Barrow-in-Furness... ... ... (S) Nov. 1885

Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884

Warburton, J., 16, Elmwood Street, Sunderland ... ... Nov. 1884

Wardale, Henry, 52, Bewick Road, Gateshead ... ... (E) Feb. 1888

Warren, Wm., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884

Watt, Adam, 11, Salem Hill, Sunderland ... ... Nov. 1884

Watt, Robert B., 1, Mitchell Street, West Hartlepool ... ... (S) April 1888

Watts, Philip, Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Nov. 1885

Waugh, G. W., Monkseaton, near Newcastle-on-Tyne ... ... (E) May 1885

Weatherall, J., 264, Wansbeck Terrace, Heaton ... (E) { Graduate, Oct. 1885 / Member, Oct. 1887

Weighton, R. L., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's (E) Nov. 1884

Weir, John, Messrs. Ramage & Ferguson, Leith ... ... (E) Nov. 1884

Welch, W. E., Brighton Grove, Newcastle-on-Tyne ... ... (S) Nov. 1884

West, Henry H., 14, Castle Street, Liverpool ... ... (E & N A) Oct. 1886

Westgarth, Tom, Messrs. Westgarth, English, & Co., Middlesbro'-on-Tees ... ... (E) Oct. 1886

Westmacott, P. G. B., Elswick Engine Works, Newcastle-on-Tyne (E) Nov. 1884

Wharrier, J., Westbourne Avenue, Walker-on-Tyne ... ... (D) Nov. 1884

White, C., 13, Mosley Street, Newcastle-on-Tyne ... ... (E) Nov. 1884

White, R. S., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Low Walker ... ... (S) Nov. 1884

Whyte, Wm., B, Lombard Street, Newcastle-on-Tyne ... ... (E) Nov. 1884

Widdas, T. D., 99, Belgrave Road, Aigburth Road, Liverpool (SUR) April 1885

Wiles, John W., 123, Clifford Street, Byker ... ... (S) Nov. 1886

Wilkie, J., 9, Croft Avenue, Sunderland ... ... (E) Nov. 1884

Willcox, F. W., 45, Sunniside West, Sunderland ... ... (E) Nov. 1884

Williams, J., 3, Azalea Terrace, Sunderland ... ... (SUR) Nov. 1884

Willis, Jos., 78, Gosforth Street, Monkwearmouth, Sunderland ... Nov. 1884

Wilson, James, 100, Brougham Terrace, West Hartlepool ... ... (E) Feb. 1886

Wilson, J. T., 27, Mather Street, Newcastle-on-Tyne (E) { Graduate, April 1885 / Member, Feb. 1886

ELECTED.

Wilson, Robert, 19, Victoria Street, Newcastle ... ... (S) Oct. 1887
Wilson, R. D., 17, Hawthorn Street, Newcastle-on-Tyne ... ... (E) Nov. 1886
Wilson, T., Messrs. General Steam Navigation Co., Deptford, London, S.E. ... ... (E) Nov. 1884
Wilson, William, 6, Victoria Street, Walker-on-Tyne ... ... (S) Oct. 1885
Winstanley, P. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick ... ... (E) Nov. 1884
Withy, H., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1884
Wright, R., 25, Westmorland Road, Newcastle-on-Tyne ... ... Nov. 1884

Y.

Younger, R., Victoria Villa, Heaton, Newcastle-on-Tyne ... ... (E) Nov. 1884

Z.

Zeltz, A., Actien Gesellschaft Vulkan, Bredow bei Stettin, Germany (E) Nov. 1884

ASSOCIATES.

A.

Allden, William R., Akenside Villa, Newcastle ... ... (A) Dec. 1886

B.

Barklam, George, Tipton, Staffordshire ... ... April 1888
Barwick, J. S., Ashbrook Grange, Sunderland ... ... (S O) Nov. 1884
Bell, John Henry, 24, Park Place West, Sunderland ... (I & S M) Oct. 1887
Boyd, Robert, Messrs. Hannay, Boyd, & Co., Quay, Newcastle ... (S O) Nov. 1884
Branfoot, W. J., Messrs. Tyzack & Branfoot, John Street, Sunderland ... ... (S O) Dec. 1887
Briggs, R. G., Moorlands, Sunderland ... ... (S O) Dec. 1886
Browne, John L., Thornhill Gardens, Sunderland ... ... (S O) Dec. 1886
Brunton, John, 3, Prior's Terrace, Tynemouth ... ... (S O) Oct. 1886

C.

Carr, Ralph, 25, Claremont Place, Newcastle ... ... (A & S O) Nov. 1886
Charlton, W. A., St. Nicholas' Buildings, Newcastle ... ... (A) Mar. 1888
Common, Francis James, 5, Elms West, Sunderland ... (I & S M) Oct. 1887
Coull, John, 43, Stanley Street West, North Shields ... ... (S O) Oct. 1886
Craven, John, The Cloisters, Sunderland ... ... (R M) Dec. 1886
Culliford, J. H. W., Sunderland ... ... (S O) Nov. 1884

D.

Dodds, Charles Henry, General Manager, River Wear Commission, 16, Thornhill Terrace, Sunderland ... ... Oct. 1887
Dunford, T. G., Messrs. Elliott, Lowrey, & Dunford, Lombard Street, Quay, Newcastle-on-Tyne ... ... (S O) Nov. 1884

F.

Fisher, Jos., Messrs. Fisher, Renwick, & Co., Queen Street, Newcastle (S O) Nov. 1884

ELECTED.

G.

Gjemre, Lauritz, **Maritime Buildings, King Street, Newcastle-on-Tyne** ... ...(S O) Mar. 1886
Green, F. W., **14, Monk Street, Monkwearmouth** ... ... (A) Nov. 1884
Greenwell, Thos. G., **Sunderland** ... ...(S O) Dec. 1886

H.

Hedley, John H., **10, Esplanade West, Sunderland** ... ... (S) Dec. 1886
Heslop, Richard O., **Akenside Hill, Newcastle-on-Tyne** ... (I & S M) Oct. 1885
Hollis, H. E. ... ... (I & S M) Feb. 1885
Hudson, Ralph M., Jun., **8, The Cedars, Sunderland** ... ...(S O) Dec. 1886
Hunting, Charles, **Jesmond Dene, Newcastle-on-Tyne** ... ...(S O) April 1886

J.

Jenkins, William, **Consett Hall, Durhamshire** ... ... (I & S M) Nov. 1887

K.

Kerr, James, **7, The Retreat, Sunderland** ... ... (A) Jan. 1888

M.

Macarthy, George E., **9, Dean Street, Newcastle** ... ...(S O) Oct. 1887
Maughan, William, **Westmorland Road, Newcastle** ... ... (A) Feb. 1887
McNabb, Thos., **Cail's Buildings, Quayside, Newcastle** ... ...(S O) Nov. 1886
Metcalf, Thomas, **6, Dundas Street, Sunderland** ... ... (SUR) Jan. 1888
Milburn, J. D., **Queen Street, Newcastle-on-Tyne** ... ...(S O) Nov. 1884
Miller, T. R., **c/o Messrs. Lamplough & Co., 72, Cornhill, London** ... ... (A & S O) Nov. 1884
Mudd, John, **Castletown Rolling Mills, near Sunderland** ... (I & S M) Nov. 1884
Mulherion, G. F., **Phillipson Street, Willington Quay** ... ... (A) Nov. 1884

N.

Newby, S., **Messrs. Thomson & Newby, 13, Bridge Street, Sunderland** ... ... (I & S M) Nov. 1884

O.

Osbourne, Jas., **Hylton, Sunderland** ... ... (S) Jan. 1885

P.

Panton, Hugh, **38, Fawcett Street, Sunderland** ... ... (I & S M) Nov. 1887
Patterson, John, **28, Belgrave Terrace, Newcastle-on-Tyne** ... (A) Feb. 1885
Patterson, Thos., **6, Argyle Square, Sunderland** ... ... (S) Jan. 1885
Pattison, W. J., **Messrs. Hunting & Pattison, Quayside, Newcastle** ... ...(S O) April 1886
Perry, Edwin, **King Street, Newcastle-on-Tyne** ... ... (A) Nov. 1885
Pinkney, D. G., **Shipowner, Sunderland** ... ...(S O) Dec. 1886
Pinkney, Thomas, **Creswell Villa, Sunderland** ... ...(S O) Dec. 1886
Pinkney, T. W., **John Street, Sunderland** ... ...(S O) Feb. 1888

ELECTED.

R.

Ramsay, J. W., Newburn Steel Works, Newburn ... ... (A) Feb. 1885
Reichwald, A., Lombard Street, Newcastle-on-Tyne ... ... (A) Nov. 1884
Reid, Andrew, Printer, Akenside Hill, Newcastle-on-Tyne ... Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Queen St., Newcastle (S O) Nov. 1884
Roberts, G., Baltic Chambers, Quayside, Newcastle-on-Tyne ...(S O) Nov. 1884
Robson, Frederick, Optician, 46, Dean Street, Newcastle ... ... Oct. 1887
Robson, Thos. 28, North Bridge Street, Sunderland ... ...(S O) Nov. 1884
Roche, W. M., 2, Thornhill Gardens, Sunderland ... ...(S O) Nov. 1884

S.

Sanderson, John, 9, The Elms, Sunderland ... ...(S O) Dec. 1886
Scholefield, A., 1, St. Nicholas' Buildings, Newcastle-on-Tyne ...(S O) Nov. 1884
Scott, W. H., Messrs. Scott Brothers, Dean Street, Newcastle ...(S O) Nov. 1884
Snowdon, W. F., Salter's Road, Gosforth ... ... (E A) Dec. 1886
Speeding, James, Roker House, Sunderland ... ...(R M) Dec. 1886
Squance, J. W., Marine Superintendent, 13, The Avenue Sunderland April 1888
Stephens, D., Messrs. Stephens, Mawson, & Co., Guildhall Chambers, Quay, Newcastle-on-Tyne, or 20, Osborne Avenue, Jesmond (S O) Nov. 1884
Swan, Isaac J., Grove House, Gosforth ... ... (S O) Feb. 1888

T.

Taylor, John W., Thornhill Tower, Sunderland ... ...(S O) Dec. 1886
Temperley, J., Cail's Buildings, Newcastle-on-Tyne ... ...(S O) Nov. 1885
Thompson, V. T., Baltic Chambers, Sunderland ... ...(S O) Dec. 1886

V.

Varley, John, 257, High Park Road, Leeds ... ... (I & S M) Mar. 1887

W.

Wait, James, Maritime Buildings, King Street, Newcastle-on-Tyne (S O) Nov. 1884
Ward, Joseph, Messrs. Wallsend Slipway Co., Wallsend-on-Tyne... (A) Nov. 1886
Welford, Richard, Gosforth, Newcastle-on-Tyne ... ...(S O) April 1888

GRADUATES.

A.

Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde, Manchester Feb. 1888
Anderson, Robert ... ... Nov. 1886
Armstrong, Walter, 36, Suffolk Street, Bishopwearmouth, Sunderland ... Dec. 1885
Armstrong, William, 63, Croft Terrace, Jarrow ... ... Oct. 1886

B.

Barnes, William, 3, High Ellison Street, Hebburn-on-Tyne ... ... Feb. 1887
Blackett, Walter, 6, Windsor Crescent, Newcastle ... ... Nov. 1886
Boyd, William, Jun., North House, Long Benton ... ... Nov. 1887
Burton, C. D., 34, Edith Street, Jarrow ... ... Oct. 1886

ELECTED.

C.

Common, F., 13, Tavistock Place, Sunderland ... ... May 1885
Coull, Alex. B., 43, Stanley Street W., North Shields ... ... Feb. 1887
Crosby, J., 1, Randolph Street, Sunderland ... ... May 1885

D.

D'Eyncourt, Eustace, 31, Cornwall Gardens, London, S.W. ... ... Dec. 1886
Dixon, John R., Warden House, Tynemouth ... ... Oct. 1887
Donkin, Samuel, 5, Dean Terrace, Southwick, Sunderland ... ... Jan. 1888
Dove, Herbert J., 28, Ashfield Terrace West, Newcastle ... ... Oct. 1887

F.

Fairbairn, Jas., 49, Harrogate Street, Sunderland ... ... May 1885
Fawcett, J., 2, Rock Street, Shieldfield, Newcastle-on-Tyne ... ... Jan. 1886
Foley, Wm. C. le B., 12, Grove Street, Newcastle-on-Tyne ... ... Nov. 1887

G.

Gaine, Roger L., 17, Park Place E., Sunderland ... ... Dec. 1887
Gayner, Robert H., Beech Holm, Sunderland ... ... Mar. 1886

H.

Hamilton, James, 14, Victoria Square, Newcastle ... ... Oct. 1887
Head, Alston G., 3, Cambridge Road, West Hartlepool ... ...
Henshall, Samuel, 9, Chester Road, Sunderland ... ... May 1885
Holey, J. T., 19, Rosslyn Terrace, Sunderland ... ... Jan. 1886

I.

Ingram, Herbert P., 30, Brougham Street, East Hartlepool ... ... April 1888

M.

Manford, Frank, 1, Osborne Terrace, Jesmond ... ... Mar. 1888
Marshall, F. T., 38, Percy Gardens, Tynemouth ... ... Jan. 1885
Metcalf, Thos., 6, Dundas Street, Sunderland ... ... May 1885
Miller, T. B., 6, Vernon Terrace, Gateshead ... ... Nov. 1886

N.

Nicholson, John, Messrs. Black, Hawthorn, & Co., Gateshead ... ... Dec. 1886
Nicolson, Gilbert C., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's Oct. 1885

R.

Reed, Joseph, 51, Fisher Street, Low Walker-on-Tyne ... ...
Rickaby, Augustine, Bloomfield Engine Works, Monkwearmouth, Sunderland ... ... Nov. 1885
Ritson, Stanley M., 18, St. Bede's Terrace, Sunderland ... ... Nov. 1887
Roberts, T. C., Neptune Shipyard, Low Walker ... ... Oct. 1886
Ross, A. T. C., 19, East Parade, Newcastle ... ... Dec. 1886
Rutherford, J. T., 80, Ryehill, Newcastle-on-Tyne ... ... Jan. 1886

ELECTED.

S.

Shaw, Thomas, West Boldon, near Sunderland ... ... Dec. 1885
Skinner, Leslie, 22, Ravensbourne Terrace, South Shields ... ... Dec. 1886
Speeding, Joseph C., Roker House, Sunderland ... ... Dec. 1886
Stoddart, Swinton, 24, North Milburn Street, Sunderland ... ... May 1885

T.

Towers, Edward, Jun., 4, Latimer Street, Tynemouth ... ... Nov. 1886

W.

Watson, R. J., Willington House, Willington Quay ... ... Jan. 1886
Westmacott, Alfred, Benwell Hill, Newcastle-on-Tyne ... ... Dec. 1885
Wheeler, O., 4, Wilberforce Street, Wallsend ... ... Oct. 1886
Windham, Harry S., 3, Cambridge Road, West Hartlepool ... ...
Wortley, H., 11, Burton Street, Byker, Newcastle-on-Tyne ... ... Jan. 1886

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 9TH, 1888.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders." Name.

II.—The OBJECTS for which the Institution is established are:—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions. Objects.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect. Honorary Members.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum. Members.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum. Associates.

Graduates.

VII.—GRADUATES shall be persons under twenty-one years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum.

Life Members and Associates.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of Twenty Guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of Ten Guineas.

Officers.

IX.—The OFFICERS of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, six Vice-Presidents, fifteen Councilmen, and an Honorary Treasurer.

Election of Officers (See Bye-Law No. 11.)

X.—The President and Honorary Treasurer shall be elected annually. Two Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall, at the end of the first year, be decided by ballot from the whole number; at the end of the second year, by ballot from the number who have served two years; and each succeeding year they shall be those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents and Councilmen shall not be eligible for re-election to the same offices until after a similar interval, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

Honorary Members' Privileges.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions.

Members Privileges

XII.—Members shall have all the privileges of the Institution, as enumerated in the foregoing paragraph, and shall be eligible for office.

XIII.—Associates shall have all the privileges enumerated in paragraph XI. They shall be eligible for office as Councilmen. Associates' Privileges.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolutions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office. Graduates' Privileges.

XV.—The General Meetings of the Institution shall be held during the winter seasons of each year. General Meetings.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

Revised at the Closing Business Meeting held on May 4th, 1887.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday. Candidates for Admission.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix. Graduates becoming Members.

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

Balloting for Members.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and shall become due on the 1st of June each year. Any member withdrawing from the Institution after that date is still liable for the amount of subscription due on that day. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of June following.

Receipt of Subscription

7.—On payment of each subscription the Secretary shall forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be unknown in the meeting shall only be able to claim the privilege in question on proving his membership for the current Session.

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to Form E in the Appendix; and in the event of its continuing in arrear until the end of that

Session after such application, the Council shall have the power, after remonstrance by letter, according to the Form F in the Appendix, of declaring that the defaulter has ceased to be a member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall, in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

Election of Officers.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be, at least, two in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary, to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the

list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, six Vice-Presidents, one Honorary Treasurer, and fifteen Councilmen, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to them as Councilmen, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting.

12.—The result of the ballot for Officers shall be declared at the General Meeting, to be held in May, at which meeting general business shall be transacted. At the May General Meeting the newly-elected Officers. after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the person whose place they fill would have retired. Vacancies not filled up during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and shall be held in Newcastle. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

Notice of Meetings.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution.

Special General Meetings.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition, signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the reqnisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

Quorum.

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special meeting.

Chairman at Meetings.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents ; or in the absence of these, a Councilman shall take the chair ; or if no Councilman be present and willing to take the chair, the meeting shall elect a Chairman.

Decisions of General Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands ; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote ; otherwise he shall not vote.

Questions of a Personal Nature in General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and

collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened.

Transactions of Business at General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed.

Dissolving a General Meeting.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

Adjourning a General Meeting.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

Introduction of Friends.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it.

COUNCIL MEETINGS.

Council Meetings.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known.

Convening Meeting for Expenditure of Funds.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business.

Discussions of a Personal Character.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential.

Regulation of Proceedings.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number.

Chairman and Quorum.

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Councilmen shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum.

Sub-Committees.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case, and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

Sub-Committees.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution.

Sub-Committees.

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best.

Invitation of Strangers.

29.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote.

Secretary and Treasurer's Duties.

30.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution.

Finance Committee.

31.—The following Sub-Committees shall be appointed annually by the Council:—(1) A Finance Committee, to consist of seven persons, viz., one Past-President or Vice-President, who shall be Chairman; five Councilmen, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary, and the Honorary Treasurer. (2) A Reading Committee, to consist of six members of Council.

Payment of Accounts.

Reading Committee.

TRANSACTIONS.

Papers to be submitted to Council.

32.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through. The Reading Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered.

Reading Committee.

Printing Transactions

33.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

Copy of Papers supplied to members before reading, etc.

34.—Copies of papers to be read during any session will be sent seven days before the date of reading to members who shall have applied to the Secretary for them, in writing, at the commencement of the session. The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting, prior to the reading of the paper set down for that date.

Proofs sent to members for Correction.

35.—Proofs of the reports of discussions shall be sent for correction to the members who have taken part in the discussion, but must be returned to the Secretary within seven days of the date on which they were sent, otherwise they will be deemed correct, and will be printed off.

Liberty to Print Explanatory Notes.

36.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

37.—The Institution shall not be held responsible for the

statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

38.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 41.

Transactions not supplied to Members in Arrears.

39.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

Members not to receive Transactions till after First Payment.

40.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

41.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. Additional copies of papers required by authors for their private use can only be procured from the Secretary, at prices fixed by the Council from time to time, and these copies must contain the whole of the discussion following the papers, and be bound in the usual cover, with the addition of the following words:—"By permission of the Council," and "Excerpt Minutes of Proceedings." Duplicate volumes and copies of parts of the Transactions, if in print, can also be obtained from the Secretary, and shall be sold only by him, in such manner and at such prices as the Council shall have fixed.

Rule of Discussion.

42.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes.

ACCOUNTS.

43.—The Council shall present the yearly accounts (up to the 31st of May preceding) at the October General Meeting of

each year, after they have been audited by a professional Accountant, appointed by the members at the General Meeting in May.

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

44 —Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the May General Meeting, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire ; but in this case it shall be read at the May General Meeting in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the May General Meeting.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19.

APPENDIX.

FORM A. (BYE-LAW 1.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned [Members or Associates], propose and recommend that he shall become [a Member, Associate, or Graduate] thereof. We know him to be [a Principal, &c., or engaged in, &c.,] and eligible for the proposed membership.

FROM PERSONAL KNOWLEDGE.

Signed_____
_____
_____
_____
} Four [Members or Associates.]

Dated this day of 18

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-one years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(*Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.*)

Signed_____
_____
_____
} Three [Members or Associates.]

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

MEMBER, ASSOCIATE, OR GRADUATE.	OCCUPATION.	ADDRESS.	NOMINATED BY.	SUPPORTED BY.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

SIR,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr._____

Address_____

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of £ : : .*"

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £
of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,
Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,
Yours faithfully,

Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be.)

I am, Sir,
Yours faithfully,

Secretary.

FORM H. (BYE-LAW 11.)

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

——— President for the current year (eligible for re-election.)*

——— } New Nominations, from whom to select ONE.

VICE-PRESIDENTS.—SIX NAMES only to be returned (including the four who remain in office), or the vote will be lost.

——— } Four Vice-Presidents remaining in office, whose seats are NOT vacant.

——— } Two Vice-Presidents retiring, and NOT eligible for re-election.

——— } New Nominations, from whom to select TWO names.

TREASURER.—ONE NAME only to be returned, or the vote will be lost.

——— Treasurer for the current year, eligible for re-election.

——— } New Nominations, from whom to select ONE.

COUNCILMEN.—FIFTEEN NAMES only to be returned, including the ten who remain in office.

——— } Ten Councilmen remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.

——— } Five Councilmen retiring, and NOT eligible for re-election.

——— } New Nominations from whom to select FIVE.

*To be crossed out before issue, when the President is not eligible for re-election

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Councilmen, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM J. (BYE-LAW 44.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,.....being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr.....
who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the.....day of ....., 18....., and at any adjournment thereof.

Signature.....

Address.....

.....

.....*Secretary.*

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887–8.

PROCEEDINGS.

ANNUAL GENERAL MEETING HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, OCTOBER 19TH, 1887.

W. THEODORE DOXFORD, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting (being the closing meeting of last session), held in Newcastle-upon-Tyne on May 4th, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. B. G. Nichol and R. L. Weighton to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Armstrong, Robert B., Dene Terrace West, Southwick, Sunderland.
Campbell, William, Belfast Shipyard, Belfast.
Clark, Henry, Southwick Engine Works, Sunderland.
Clarke, William, Victoria Works, Gateshead.
Gordon, William James, 136, Blake Street, Barrow-in-Furness.
Hardy, Arthur Francis, } Germania Werft, Gaarden bei Kiel, Germany.
Helyer, A. J., }
Hall, John W., Abden Shipyard, Kinghorn, N.B.
Kellner, T.
Littleboy, Chas. Wm., 12, Shaftesburn Street, Stockton-on-Tees.
Orde, E. L., Orde House, Morpeth.

Perrett, J. Richard, 14, Rokdale Terrace, Jesmond.
Ralston, G. C., 82, Tamworth Road, Newcastle.
Rella, C. de Grave, c/o Messrs. Gio Ansaldo, Sampierdarena, Genoa, Italy.
Spear, John, Messrs. T. Wilson & Sons, Hull.
Scott, Joseph R., 9, Queen Street, Newcastle.
Surtees, A. W., Frame, Low Teams, Gateshead.
Tucker, Joseph W., Wallsend.
Wallen, T. W., Mount Stuart Dry Docks, Cardiff.
Wilson, Robert, 19, Victoria Street, Newcastle.

GRADUATES DESIRING TO BECOME MEMBERS.

Curwen, Henry R., Gaarden bei Kiel, Germany.
Davis, Albert, c/o Messrs. Hutcheson, Rowand Road, Dumbarton, N.B.
Head, Archibald P., 20, Elswick Row, Newcastle.
Heavell, W., 40, Heaton Road, Newcastle.
Tone, John M. F., 50, Clayton Park Square, Newcastle.
Weatherall, J., 264, Wansbeck Terrace, Heaton.

ASSOCIATES.

Bagnall, George R., National Provincial Bank of England, Limited, Sunderland.
Bell, John Henry, Monkwearmouth Iron Works, Sunderland.
Common, Francis James, 5, Elms West, Sunderland.
Dodds, Charles Henry, 16, Thornhill Terrace, Sunderland.
Eccles, Edward, 6, Exchange Buildings, King Street, Newcastle.
Macarthy, George E., 9, Dean Street, Newcastle.
Robson, Frederick, 46, Dean Street, Newcastle.

GRADUATES.

Coles, J. Howell, 2, Grosvenor Place, Newcastle.
Dixon, John H., Warden House, Tynemouth.
Hall, Herbert J., 38, Ashfield Terrace West, Newcastle.
Hamilton, James, 14, Victoria Square, Newcastle.

The SECRETARY read the Council's Report and the Treasurer's Financial Statement for the last session, as follows:—

COUNCIL REPORT.

(THIRD SESSION.)

THE Council has pleasure in stating that the finances of the Institution are in a satisfactory condition.

During the third session the following six papers of practical importance have been read and discussed:—

1.—"Use and Transport of Liquid Fuel." By Messrs. B. G. Nichol and J. Gravell.
2.—"The Plan and Construction of Marine Engine Works." By Mr. Thomas Mudd.
3.—"The Principle of Work in relation to the Strength of Structures." By Mr. Henry Foster.
4.—"Some Notes on the Launching of Vessels." By Mr. H. G. Gannaway.
5.—"The Reaction and Efficiency of the Screw Propeller." By Mr. A. Blechynden.
6.—"Compound *v.* Triple Expansion Engines, from a Shipowner's Point of View." By Mr. J. Percy Hall.

Another paper, on "Technical Education for Engineers and Shipbuilders," was intended to have been read during the month of January last, but owing to the melancholy death of the writer, the late Mr. Ivan Mavor, it was agreed that it should not be read before the Institution, but that it should be printed and published in the volume of the Transactions.

The late Mr. Ivan Mavor was the chief moving spirit on the sub-committee appointed "to Compile Statistics and Report upon the Progress in Shipbuilding both in Great Britain and Foreign Countries during the last twenty-five years," and previous to his death these were chiefly collected. Since his decease the work has been ably carried on by Mr. H. Macoll who has tabulated the results, and the details will most probably be placed before the Institution during the ensuing session.

The other sub-committee appointed last year "to Investigate and endeavour to formulate a simple but comprehensive Rule or Measure of the Power of Marine Engines and Boilers, which being (in a measure) scientifically sound and commercially convenient, shall be applicable to the various types and proportions which may obtain in practice," has held several meetings, and, under the chairmanship of Mr. William Boyd (Past-President), who was appointed to succeed the late Mr. W. J. Clark, has endeavoured to recommend a formula for determining the nominal horse-power of any set of marine engines in the terms of the original

resolution passed by the Institution—but the more the question is investigated the more difficult does the task appear—and up to the present time the committee has been unable to propose a formula which it could recommend for general acceptation. The labours of the committee, however, are not yet closed, and an effort will be made to make a communication on the subject to the Institution during the coming winter.

On the 30th of October, 1886, the President, Mr. W. Theo. Doxford, received the following letter from Professor Garnett, M.A., D.C.L., Principal of the Durham College of Science :—

[COPY.]

DURHAM COLLEGE OF SCIENCE,
NEWCASTLE-UPON-TYNE,
30th October, 1886.

To the President of the North-East Coast Institution of Engineers and Shipbuilders.

MY DEAR SIR,

I am venturing to write to you in your double capacity of President of the North-East Coast Institution, and of Governor of the Durham College of Science.

You are aware that the College has purchased an extensive site (6¼ acres), and intends within a few weeks to commence erecting thereon a portion of the permanent building, the block plans for the whole of which have been prepared. In these plans provision is made for *technical* departments in Mechanical and Civil Engineering, Naval Architecture, Mining, Electrical Engineering, Chemical industries, including Metallurgy and some smaller subjects, but no details of the building which is to accommodate these departments, or of the course of instruction to be pursued therein have yet been decided upon. The block immediately to be erected will comprise the departments of pure Chemistry and Physics, and these have been elaborated in full detail. I hope soon to make some progress with the departments of Electrical and Mechanical Engineering and Naval Architecture, but here, as in other technical departments, I wish to take no serious step without the full concurrence and support of those most interested in the questions involved, I mean the local representatives of the respective industries. I shall therefore be glad if you could see your way to inviting a conference of Engineers and Shipbuilders for the purpose of discussing:

1. What subjects should be taught.
2. How the teaching should be conducted.
3. What appliances are desirable, and how they should be obtained.

The discussion should be based on the assumption that we are starting *de novo* to provide an Engineering College which is to be made as useful as possible to the trade of the district, and my hope is that it will result in the appointment of a Committee of Engineers and Shipbuilders, who, acting in conjunction with the College Council, will take the general supervision of the Engineering department, both as regards its equipment and its curriculum. Something of this sort has been done at Leeds, and the department has been well supported by the local firms. To command the confidence of practical men the course of instruction must be inaugurated by, and carried on under the direction of, the leading engineers of the district.

If you could see your way to take the initiative in this matter and to enlist the sympathies of the Council of your Institution, I should be very grateful.

Very faithfully yours,

WM. GARNETT.

On the invitation of the President, a conference of the leading Shipbuilders and Marine Engineers of the district was held in Newcastle-upon-Tyne on the 18th of December following. At that meeting it was unanimously agreed that a Chair of Naval Architecture and Marine Engineering should be established in the new College about to be erected, and a committee, consisting of the Council of the Institution and several prominent gentlemen of the district, was formed to confer with Professor Garnett and the Council of the College as to the various questions involved, and to draw up a scheme of instruction. The "scheme of instruction" has been already agreed upon, and copies can now be obtained by anyone interested on application to the Secretary of the Institution. But the chief question which is at present engaging the attention of this committee is the best method of raising the necessary funds for carrying out the scheme, the sum required being about £25,000.

On the suggestion of Sir Benjamin C. Browne, the Right Worshipful the Mayor of Newcastle, it was agreed by the Council of the Institution to send an invitation to the Institution of Naval Architects to hold a summer session in Newcastle. The invitation having been accepted by that Institution, an executive committee was appointed to carry out all the necessary arrangements. The whole of the expense incurred was met by a fund guaranteed by most of the leading shipbuilding and engineering firms of the district; and the Council, on behalf of the Institution, now takes the opportunity of thanking them for their kindness and support, together with those firms who, by throwing open their works for inspection and entertaining the visitors, contributed so ably towards the success of the visit.

The Council has had under consideration Article V. of the Constitution, with a view of increasing the subscription of 10s. 6d. paid by one class of members. It was however agreed that the Constitution stand in its original form for the present, and be reconsidered during the ensuing session. Sundry other alterations were made in the Bye-Laws, of which the following are the chief:—

1.—That Associates shall be eligible as Councilmen.

2.—That the Secretary shall also act as Treasurer to the Institution.

3.—That no debate shall be considered closed the same night on which the paper discussed is read, but shall be open for further consideration at a following meeting (providing always that the writer of the paper has not replied to the remarks made in the debate).

The Council feels the importance of establishing a Reading Room for the use of the members of the Institution; but before asking the mem-

bers to express their views on the subject, the Council will lay before them, at an early date, an estimate of the expense which would be incurred.

During the session 87 new Members, 22 Associates, and 25 Graduates have been enrolled, and 12 Graduates have been raised to the rank of members. The Institution has lost by death 6 Members; by resignations, etc., 34 Members, 4 Associates, and 5 Graduates.

The names of the deceased members are as under :—

John Brockat, of Lloyd's Register of Shipping, Newcastle-on-Tyne.
J. W. Clark, of Southwick, Sunderland.
F. E. Davis, of Wallsend-on-Tyne.
C. Dobson, of Low Walker-on-Tyne.
W. J. Hoyle, Bentinck Villas, Newcastle-on-Tyne.
Ivan Mavor, Hebburn-on-Tyne.

Messrs. Brockat and Mavor were members of the Council at the time of their decease. Mr. Clark was likewise a member of the Council, but had resigned his seat previous to his death.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

STATEMENT OF RECEIPTS AND PAYMENTS FOR SESSION ENDING 31ST MAY, 1887.

Receipts.

	£	s.	d.	£	s.	d.
To Balance from last Account—						
At Bankers	30	0	4			
In hand	8	5	9			
				38	6	1
„ Subscriptions received for Session, 1886–7—						
140 Members at £2 2s. £294 0 0						
55 Associates „ £1 1s. 57 15 0						
343 Members „ 10s. 6d. 180 1 6						
58 Graduates „ 5s. 0d. 14 10 0						
	546	6	6			
For Session 1885–6 (Arrears)—						
5 Members at £2 2s. £10 10 0						
4 Associates „ £1 1s. 4 4 0						
12 Members „ 10s. 6d. 6 6 0						
	21	0	0			
				567	6	6
For Session 1887–8 (in advance)—						
4 Members at 10s. 6d.				2	2	0
Life Membership—						
David Hallé				21	0	0
„ Transactions—						
Per Secretary	47	5	6			
„ F. C. Marshall	11	0	0			
„ W. T. Doxford	1	6	6			
„ J. Gravell	6	2	0			
„ T. Mudd	5	5	0			
„ H. Foster	8	6	0			
„ A. Blechynden	3	2	6			
„ J. P. Hall	13	7	6			
				95	15	0
				£724	9	7

Payments.

	£	s.	d.	£	s.	d.
By Andrew Reid—						
Balance from Session 1885–6 ... ... £80 9 0						
Transactions, 1886–7 ... 333 6 9						
	413	15	9			
Less—Balance unpaid	38	17	3			
				374	18	6
„ General Stationery	42	9	0			
„ Reporting	14	2	0			
„ Advertising	12	10	0			
„ Rents	11	7	0			
„ Salaries	85	0	0			
„ Secretary's Expenses and Postages ...	71	1	10			
„ Treasurer's „ „ ...	2	1	0			
„ Sundries	1	11	0			
„ Auditor's Fee	1	11	6			
				241	13	4
„ Office Furniture				1	10	0
„ Balance—						
At Banker's	89	10	9			
In hand	16	17	0			
				106	7	9
				£724	9	7

Revenue Account for Session ending 31st May, 1887.

	£ s. d.	£ s. d.
To Expenditure as per Cash Account ...		241 13 4
„ Transactions Account—		
Stock at beginning of Session	110 12 0	
Cost of Transactions during Session, viz.:		
Printing £162 14 9		
Lithographing ... 140 14 6		
Authors' copies ... 17 5 6		
Binding 10 19 0		
Covers 1 13 0		
	333 6 9	
	443 18 9	
Less—Sales during Session 84 11 0		
Stock at end of Session 144 0 0		
	228 11 0	
		215 7 9
„ Balance, being Surplus at end of Session		265 14 8
		£722 15 9

	£ s. d.	£ s. d.
By Balance from last Session		133 6 9
„ Subscriptions Account—		
Amounts payable for Session 1886-7, viz.:		
150 Members, £2 2s.	315 0 0	
60 Associates, £1 1s.	63 0 0	
367 Members, 10s. 6d.	192 13 6	
67 Graduates, 5s.	16 15 0	
	587 8 6	
Less—Arrears for Session 1885-6 written off	18 19 6	
		568 9 0
„ Life Member		21 0 0
		£722 15 9

THE BALANCE SHEET.—31ST MAY, 1887.

Liabilities.

	£	s.	d.
ANDREW REID—			
Balance of Account	38	17	3
SUBSCRIPTIONS FOR SESSION 1887-8—			
Paid in advance	2	2	0
SURPLUS as per Revenue Account	265	14	8
	£306	13	11

Assets.

				£	s.	d.	£	s.	d.
SUNDRY DEBTORS—									
For copies of Transactions sold... ...							8	16	6
SUBSCRIPTIONS in arrears, viz.:									
Arrears from last Session	£40	15	0						
Subscriptions payable for Session 1886-7, as per Revenue Account ...	587	8	6						
				628	3	6			
Less—Subscriptions paid as per Cash Account	567	6	6						
Arrears written off ...	18	19	6						
				586	6	0			
							41	17	6
STOCK OF TRANSACTIONS, viz.:									
20 copies, Vol. 1, bound } 155 „ „ 1, unbound }				30	0	0			
13 „ Vol. 2, bound } 109 „ „ 2, unbound }				64	0	0			
100 „ Vol. 3, unbound				50	0	0			
							144	0	0
OFFICE FURNITURE							5	12	2
CASH at Banker's				89	10	9			
„ in hand				16	17	0			
							106	7	9
							£306	13	11

Newcastle-on-Tyne, 6th October, 1887.

Audited and Certified,

R. W. SISSON.

The PRESIDENT, before moving the adoption of the Report, asked to be allowed to refer to one or two points. First, as regarded the Chair of Naval Architecture and Marine Engineering, the Committee was very anxious that the scheme should be carried out, but the cost of doing so in a manner worthy of the district was so great that he, for one, hesitated to appeal to the public for the amount in these depressed times. However, at their last meeting there were some suggestions made which they hoped might lead to some material assistance. The next matter to which he wished to allude was the visit of the Naval Architects in July last. He need hardly say, for they were quite cognisant of the fact, that the meetings then held were in every way successful. When their Council decided to give the invitation they felt that they were undertaking a great responsibility, and that the visit could only be made a success by the hearty co-operation of all concerned. Fortunately, their appeal for assistance was responded to, both financially and by invitations to visit works, in such a spirit that he (the President) felt assured that success was certain. There was no need for him to refer further to what took place that week as they had a personal knowledge of it all, but he might take this opportunity of publicly thanking, on their behalf, all those gentlemen who so generously assisted in making the visit of the Naval Architects, both intellectually and socially, the great success it proved. He thought he might further be allowed to express their thanks to the Noble President and members of the Institute of Naval Architects for having so readily accepted their invitation, and for having afforded them the opportunity of meeting and associating with them, and by this communion, benefitting from their superior experience. There was another question, a rather important one, that with regard to the 10s. 6d. subscriptions. It was really a very vexed question; for, although the 10s. 6d. did not cover the cost of the "Transactions" and other expenses, yet as this subscription applied to a class of members to whom they wished to give every encouragement, they were loth to make any increase. At the same time, when they considered that if this subscription were increased to one guinea, and they maintained their present numbers, they could open a reading-room, where the members could see the whole of the technical papers of the day, as well as the transactions of kindred institutions, thereby exciting a mutual feeling and interest that might lead to their establishment of a club. He thought that a guinea subscription would not be too much to pay for such privileges. In regard to the accounts, he would just point out that by the increase in the number of members, and a reduction in the cost of printing, etc., their

position that day was better by £132 than it was twelve months ago. At that time their surplus was only £133, now it was £265. This was not all cash, for they had the "Transactions" in stock which were valued at £144. He would not go into details, as they had the accounts before them, and before moving the adoption of the Report he would be pleased to hear any observations upon it.

Mr. JOHN GRAVELL said, that from the statement of accounts he observed that about two-thirds of their members really did not pay, in their subscription, the cost price of the "Transactions," of which each received a copy. The Transactions cost the Institution something like 12s. per head, and thus he thought the subscription of 10s. 6d. rather low. As the President had mentioned, he (Mr. Gravell) thought it should be at least a guinea, especially now that they had a scheme in view for the establishment of a reading-room. The funds would hardly stand that additional strain without putting an extra levy upon the contributors of 10s. 6d. He was further of opinion that the graduates' subscription of 5s. was too low, and that 10s. 6d. would not be at all too much for them to contribute to the funds.

Mr. B. G. NICHOL thought it might be of some advantage to the members, in considering whether the subscriptions should be increased or not, if they had before them a rough analysis of the accounts as they had been presented. Last year the available cash balance—that was cash in bank and cash in hand—was £38 6s. 1d.; but at that time they owed £80 9s., which practically left them in debt, so far as available cash was concerned, to the amount of £42 2s. 11d. Now, at the end of the last session, the available cash balance was £106 7s. 9d. Deducting from that amount the sum since paid to Mr. Reid (printer), £38 17s. 3d., they had a net sum available of £67 10s. 6d. Adding to this the £42 2s. 11d. which they had paid to make up the balance for the previous year, it showed the actual amount gained during the session to have been £109 13s. 5d. They would notice that the arrears of subscriptions were practically the same this year as they were last, and it was in every way likely that there always would be some arrears, and in all probability they would stand at something like the same amount. They could not reckon much on the £109, and he did not think, in fact, that they were entitled to do it, for during the year they had a life member enrolled, and that might not occur every session. They had also sold £47 5s. 6d. worth of "Transactions" which were in stock, and they could not rely on that amount being realised annually. Further, they had already decided, as they were aware, to increase the Secretary's salary, seeing that he now did

the work of Treasurer, and this meant a net increase of £35—actually the increase was £45, but the £10 formerly paid to an Assistant Treasurer reduced it to the £35. They had not paid anything for the maintenance of the measured mile-posts, and probably £5 would have to be expended this year. Altogether, he thought it was just likely, things remaining as they were, that they might have a very small balance (if any) at the end of next year. It appeared to him that there was not the slightest shadow of a chance of having a reading-room unless the subscriptions referred to were increased.

The PRESIDENT said, that with regard to the matter to which Mr. Gravell referred, he should point out that it was still before the Council. It was intended to get an estimate of the cost of the reading-room, and to make a special report to the members as soon as possible.

The PRESIDENT put the adoption of the Report to the meeting and declared it carried.

PRESIDENT'S INAUGURAL ADDRESS.

READ BEFORE THE INSTITUTION AT THE ANNUAL MEETING, OCT. 19TH, 1887.

CONSIDERING the great importance of the subject, I will, with your permission, refer to some of the points I had the honour of bringing before you twelve months ago. At that time I wished to show what prospect we had of improved trade for engineers and shipbuilders, and the figures which I then gave and the conclusion I then drew, though somewhat startling, I have not seen seriously questioned by anyone of authority; indeed in many cases they have been adopted by eminent speakers and writers as substantially correct. It may therefore be instructive if I summarise as shortly as possible what I then said and see how far my conclusions are supported by what has been done during the past twelve months.

In the first place I took the gross tonnage of the steamers then in Lloyd's "New Universal Register" of 200 tons and upwards as 9,855,560 tons, and showed :—

1.—That the general tendency was to increase the average size of steamers.
2.—That 44 per cent. of those steamers had been built during the years 1881–6.
3.—That at least 3,000,000 tons of steamers required to be re-engined or to have their present engines altered to triple expansion.
4.—That the gain to the owner would be at least 30 per cent. per annum upon the cost of alterations.
5.—That there should be an average of £2,000,000 per annum spent over alterations and repairs during the next ten years.

I am not now going to deal with each of these points but only with that one which is of most importance to us at present, viz., the amount of work to be done to old steamers to render them efficient.

It is important to us to know what proportion of that work has been done since the beginning of 1886, and to thus ascertain how far shipowners have appreciated their position.

Unfortunately, I have not got complete returns for the whole kingdom, but I find that the following vessels have been or are being altered on the East Coast, Clyde, and Mersey, and at Aberdeen, viz. :—

6	steamers,	gross tonnage about	5,652,	have been re-engined	with	compounds.
24	„	„	„ 50,399,	„	„	„ triples.
2	„	„	„ 5,632,	„	„	„ quadruples.
41	„	„	„ 94,517,	have had old engines	altered	to triples.
5	„	„	„ 11,106,	„	„	„ quadruples.
Total 78			167,306			

Say 3 per cent. in numbers of estimated total and 5½ per cent. in tonnage, showing that it is the larger class of vessels which is being altered. The percentages appear small but they will increase year by year as owners become convinced of the necessity of incurring the expense.

It is interesting to note that practically all the alterations are being made to triples, the reason being that there is no gain in using four cylinders with present pressures of steam.

It is further interesting to note that the East Coast more than holds its own in this special class of work, the seventy-eight vessels being divided as follows, viz.:—

Altered on North-East Coast	43 vessels.
„ Clyde	17 „
„ Mersey	14 „
„ at Aberdeen	4 „

This certainly should be satisfactory to the members of this Institution, showing as it does the favourable position this district now stands in.

Whilst on this subject it may be of interest if I give you the following figures for new vessels built during the past and current years, or now in hands, as further showing the rapid change to triple expansion, viz. :—

	Fitted with Compound Engines.	Fitted with Triples.	Fitted with Quadruples.	Total.
On the North-East Coast	69 ...	244 ...	— ...	313
Clyde	42 ...	85 ...	7 ...	134
At Liverpool	7	15 ...	...	22
Aberdeen		5	...	5
	118	349	7	474

Again we see the East Coast well in front of other districts, the triples, as compared with compounds, being nearly as four to one against only two to one elsewhere.

Although the figures I have dealt with do not represent the total for the kingdom, they are, I think, near enough to that total to give us an idea of what has been done, and after considering them no owner need hesitate as to which type of engine to adopt if he wishes to keep up with the times, for it may be taken for granted that the greater part, if not the whole, of the 118 compounds are compounds simply because they were built or contracted for before the triples had definitely proved their superiority.

As regards the gain to the shipowner, I have seen nothing to cause me to modify the opinions I expressed twelve months ago, but a great deal to confirm them.

Allow me here to thank Mr. W. Parker, of Lloyd's, who has specially collected the statistics from which the above figures have been condensed, for without his assistance, which was given with his usual readiness to assist others, it would have been impossible to get such reliable data.

Let us now turn to another important subject, viz., the comparative tonnages of 1886 and 1887. This question has been much dwelt on lately; nevertheless, the following figures will probably be of interest to you, showing as they do the increase or decrease in each class more clearly than I have seen them put before :—

	1886.		1887
Total Steam tonnage of Wood	356,307	...	380,655
„ „ Composite ...	32,010	...	32,820
„ „ Iron	8,907,199	...	8,911,406
„ „ Steel	995,725	...	1,206,962
Total	10,291,241	...	10,531,843

= 240,602 increase in steamers.

	1886		1887
Sailing Ship tonnage of Wood... ...	8,606,225	...	8,104,060
„ „ Composite ...	131,034	...	126,651
„ „ Iron	2,396,179	...	2,078,777
„ „ Steel	83,177	...	102,319
Total	11,216,615	...	10,411,807

= 804,808 decrease in sailing vessels.

Showing a slight increase in each description of steamer, but a large decrease in all classes of sailing vessels with the exception of the steel class, which shows a slight increase.

Now these figures show a considerable decline in the gross tonnage of the world, and, therefore, if the present depression was caused by an excess of tonnage, this is now being gradually rectified.

But, say some, we as shipbuilders have now a formidable foreign competition to contend against; and, as there has been great anxiety displayed about the development of shipbuilding in foreign countries, let us examine what has been done during the past year as regards the new tonnage built.

Taking the following six countries, I find that the new vessels added to their fleets were :—

		Built in United Kingdom.	Built elsewhere.	Of these latter built of Wood.
United Kingdom...	Sail ...	91,838 ...	395 ...	395
„ ...	Steam ...	205,945 ...	1,432 ...	1,432
France	Sail ...	2,408 ...	1,347 ...	1,347
„	Steam ...	4,007 ...	10,910 ...	266
Germany	Sail ...	— ...	12,939 ...	4,479
„	Steam ...	16,942 ...	31,057 ...	—
Italy	Sail ...	1,527 ...	5,555 ...	5,555
„	Steam ...	4,879 ...	— ...	—
Norway	Sail ...	— ...	5,850 ...	4,618
„	Steam ...	— ...	1,470 ...	359
Sweden	Sail ...	— ...	1,262 ...	1,262
„	Steam ...	197 ...	4,056 ...	203
Totals		327,743 ...	76,273 ...	19,916

So that, out of a total of 404,016 tons registered by these six countries during the year 1886-7, 327,743 tons were built in the United Kingdom and 76,273 tons were built elsewhere; but out of these 76,273 tons no less than 19,916 tons were wood or composite, leaving only 56,357 tons of iron and steel vessels built out of, as against 327,743 built in, the United Kingdom.

	Tons.	Built in United Kingdom.	Built elsewhere.
Of these France built for herself	10,644	6,415	—
„ Germany „ „	37,207	16,942	2,310
„ Norway „ „	2,343	—	—
„ Sweden „ „	3,378	197	475
Total	53,572	23,554	2,785

From these figures we find that Germany and France are the only countries which produce any appreciable quantity of iron or steel tonnage, although Sweden and Norway produce what little they require for their

own use; that Germany is fast becoming a shipbuilding country, already producing two-thirds of her fairly large requirements; and that France produces less than two-thirds of her requirements, although these are less than one-third of Germany's.

We further find that no country in the world, excepting the United Kingdom, is at present able to supply a market outside of itself, and that, therefore, with the exception of the four countries named, the whole world is dependent upon the shipbuilding yards of this country for its fleets.

To put it in another way, the total tonnage of iron and steel vessels is 10,118,012 tons, of which 3,631,963 tons are owned by foreigners; or say, 31·25 per cent., whereas the percentage of tonnage built last year by foreign countries was only 17 per cent., so that the remark made by the Noble President of the Institute of Naval Architects, in his address on the 30th March, this year, viz. :—"Formerly, England used to build ships for all the world, and now all the world is building ships for itself," is hardly correct, and I am sure that no one will be more pleased than his Lordship to know this. But although his Lordship's words may not be quite correct at the present moment, they may only too soon become true; for though we probably need not fear competition from France, assuredly we may fear it from Germany, even if not from Norway and Sweden, where they have the material and also a hardy population. Spain will also try to compete with us, especially on the northern coast where she has raw material at hand, and has already erected blast-furnaces and rolling mills—the climate may be somewhat against her, but everything else is in her favour; for although the iron ore may soon become sufficiently scarce to make it less able to compete in this country with our native ores in price, it will assuredly supply all home demands for many generations to come.

And what of America? Although her present fiscal policy practically prevents her having a mercantile fleet at all; were this changed we might have a very large demand to supply for a time, but this would be only temporary as she would ultimately produce at least the greater part of her tonnage requirements, even if she were unable to enter into competition with us in other markets.

Well then we have arrived at this point. We have a decreasing tonnage which must assuredly lead to an increased demand. We have the possibility of an abnormal demand from America, and we have the fact that no country excepting the United Kingdom is in a position to supply a demand outside of itself at the present moment. The outlook for the immediate future, therefore, should not be discouraging to shipbuilders

and engineers. But we must not expect the large demand and high prices we had four or five years ago, for the world is proportionately better supplied with tonnage than it has ever been before, and assuredly as soon as there is a tendency for prices to become excessive we will see an enormous development in the production of foreign countries; it is only by keeping our prices down, whilst we at the same time maintain the lead in all improvements that we can keep other countries in check and so retain the bulk of the trade in our own hands.

But let us see whether or no we are keeping ourselves well to the front in all improvements, and to do so we must not be afraid of pitting ourselves against the world at large. Now, the question of steel *versus* iron is one of the most important questions of the day; and is being undoubtedly settled in favour of steel. Then how do we stand upon this question? Well, there were built last year in :—

	United Kingdom. Tonnage.	Elsewhere. Tonnage.	Whole World. Tonnage.
Steel vessels ...	211,242	24,505	235,747
Iron vessels ...	186,160	43,248	229,408
Wood and composite vessels	2,309	75,618	77,927
Total	399,711	143,371	543,082

These figures clearly show that we are not slow to adopt improvements but rather that we are much more ready than the rest of the world to do so; for whereas we have practically ceased the building of wood and composite vessels, more than one-half of the total built elsewhere are still of these obsolete types, and iron vessels are nearly as two to one of steel, whereas we are building considerably more of steel than of iron.

Whether we can keep our costs down or not so as to continue to compete favourably with other countries in face of their lower wages, longer hours, and increasing facilities for the production of the necessary materials, I dare not predict for time alone can tell.

Now, as regards steel, you are well aware that there are two methods of producing it for shipbuilding purposes—one the acid process, the other the basic process, and to both of these methods of producing steel either the Siemens-Martin process of converting or the Bessemer process of converting are applicable.

Up to recently we in this district were placed at a considerable disadvantage as against our friendly rivals on the Clyde by the introduction of acid steel made by the Siemens-Martin process, owing to the difference in carriage, that material not being then produced in this neighbourhood; but fortunately, by the energy and foresight of the Consett Iron Co.,

Messrs. Palmer, and others, we are now in even a better position than our friends on the Clyde. But that is not all. You will all remember the two able papers read in Sunderland on the 27th July last, one by Mr. W. H. White "On some recent experiments with Basic Steel," and the other by Mr. B. Martell "On the present position occupied by Basic Steel as a material for Shipbuilding." These were both important papers in that they helped to restore faith in a material the manufacture of which is peculiarly favourable to this district on account of the enormous beds of ore in the Cleveland Hills, which otherwise could not be utilised in the manufacture of mild steel. Basic steel has been, to say the least of it, under a cloud, owing to a want of uniformity in its quality; but Mr. White showed that uniformity was obtainable with care, and that this make of steel was being used by the Admiralty, and Mr. Martell, although pointing out the difficulties that Lloyd's had had to contend with in the past, spoke much more hopefully of the future, having had some very satisfactory experiments made at one works, which showed that good reliable basic steel could be made if proper means and care were adopted in its manufacture. When we consider the important positions held by the gentlemen who read these papers, one being the head of the constructive department of the Admiralty, and the other the chief surveyor of Lloyd's, and, further, the standing of the eminent gentlemen who carried on the discussion, I think that the result cannot be otherwise than beneficial to the steel trade of this district, and we may fairly congratulate ourselves on having had something to do with the bringing of it about.

Bearing on this question of steel it may be interesting to look back a few years, so as to realise the advances which have been made. Now, I was very much struck by the following words written by Mr. Parker of Lloyd's, not ten years ago, in a paper read before the Institution of Naval Architects, "On the use of Steel for Marine Boilers." They were these:— "The pressures meanwhile have been slowly but steadily advancing from 60 lbs. to 75 lbs., now a common pressure, and in a few instances 90 lbs. has been reached. But up to the present all attempts which have been made with new forms of boilers, with the view of obtaining still greater pressures, have uniformly been signal failures. The recent adoption of mild steel for marine boiler making, however, will enable the present form of boiler to be made of greater strength, and gives promise of further advancement in the direction of higher pressures; and if experience is satisfactory as regards the comparative durability of steel and iron boilers, it may not unreasonably be expected that this material may

become almost universally used for their construction. Some months ago the employment of steel for such purposes was ventured on by only one or two firms, but it is now coming into more general use." Then, after referring to the recent improvement in the furnace, viz., that patented by Mr. Sampson Fox, and now universally used, he goes on to say:—"If the improvements I have indicated prove, as I have little doubt they will prove, successful, we shall have gained an advantage represented in the aggregate by an increase of about 80 or 90 per cent. of the working pressure. In other words, we shall be able to work the present form of boiler at 160 lbs. or 170 lbs. per square inch; and, although the resultant economy will not be so great as that which attended the increase at one step from 30 lbs. to 60 lbs., we may confidently anticipate that it will be sufficient to give a great impetus to steam navigation, advancement in which has been so much retarded by the high consumption of fuel."

Could any words have been more strikingly fulfilled? 160 lbs. is now an ordinary pressure, and every boiler without exception is made of steel! Nothing could show better the great foresight of the writer or the enormous advance which has taken place since the paper was written.

The successful introduction of steel has then given us the 160 lbs. pressure, and this again has enabled us to introduce the triple expansion engine which has been so much written about, and which has proved so eminently successful in every way. But we are not to stop here, for there is no finality in such work as ours. Then in what direction are we now to move? Well, without going into the question of an improved boiler, which may some day enable us to safely work up to much higher pressures than we are now using, we have three important directions in which it has been suggested we may work for improvement, viz.:—

Forced draught;
Increased piston speed;
Reduced weights.

Taking first the application of forced draught. This would materially reduce the weight of boiler necessary for a given horse-power, and members of this Institution have done something, I am proud to say, towards its satisfactory introduction. In the first place, the subject was forcibly brought before us in the first Presidential Address to this Institution, and this was followed up by the able paper by Mr. James Patterson and Mr. Magnus Sandison last year, who expressed as their opinion that "forced draught is destined ere long to supersede almost entirely the use of natural draught." This paper was followed by a more than ordinarily

interesting and able discussion, which was taken part in by some engineers of considerable experience in this special subject, who one and all appeared to be of opinion that forced draught would ere long be adapted to mercantile steamers with economical results.

Now, although that paper has been followed up by others upon the same subject read before other institutions, it is not yet exhausted, and should be kept well before us, and it behoves us to consider well whether or no we can act upon the suggestion thrown out by the authors, viz., "carefully conducted experiments on the lines indicated. This, surely, is not going beyond the scope of an Institution with a membership of upwards of 500, amongst whom are representatives of all the leading firms on the North-East Coast."

Since these words were written several more or less satisfactory experiments have been made in various parts of the country. One I will specially mention as showing the great importance of persevering in the face of the greatest discouragement. There were two new steamers built for this experiment identical in every way, excepting that one had forced draught fitted to her boilers and the other had not.

The boilers with the ordinary draught burnt 10 tons per day, and those with forced draught on the first trial 12 tons. Well, this result, with ordinary people, would have settled the question as far as they were concerned in favour of ordinary draught; but, fortunately, these experiments were continued with the view of finding out the cause of the excessive consumption, and the pressure of air was reduced from $2\frac{1}{2}$ inches, at which the first trial was made, to half an inch. The furnace bars were lengthened, baffle plates, or retarders, as they are called, were fitted in the tubes, the air openings from the fans to the furnaces were enlarged, and a number of other alterations were made from voyage to voyage, until the consumption fell to 8 tons, or 33 per cent., a saving of 20 per cent. over ordinary draught. This experiment showed that with that type of boiler a low forced draught was most economical, the result of course depending in a great measure upon the proportion of heating to grate surface, and further that a considerable saving in fuel may be effected by the judicious employment of forced draught, a result which has been doubted by many.

Now, I wish to impress upon you the great importance of this question of forced draught, because it is probably *the* debatable question of the day; and as in the vessels that have been fitted with it, where owners have persevered in order to obtain the best result, it has been clearly demonstrated that its principles are sound, it will, I think, mark the next decided step

in advance in marine engineering. The possibilities it may lead to are as yet unknown, for we have not yet got over all its difficulties; there is therefore ample scope for experiment in this direction.

As regards the other two questions, viz., increased piston speed and reduced weights, I do not feel myself competent to speak, for where eminent engineers differ in opinion, as they do upon these subjects, it would be dangerous for one not an engineer to express a decided opinion. But when we consider that in Mr. Hall's paper, read April 20th, this year, before our Institution, he gave the weight of triples, as used in the mercantile marine, at 450 to 460 lbs. per horse-power, and that Mr. Marshall, in his paper read in this room, on the 26th July, before the Institution of Naval Architects, shows that by forced draught and higher piston speed his firm has reduced the weight in war vessels to considerably under 200 lbs. per horse-power—in two special cases as low as 84 lbs. per horse-power!—although for many reasons it is not advisable for us to aim at reducing mercantile engines to anything like the weight of those put into war vessels, yet there must surely be room for some saving between 460 lbs. and 200 lbs. per horse-power—probably by using stronger material—without endangering the strength of the machinery.

If not taking up too much of your time, I would like to refer to another very important question, viz., the rapid development in the size and speed of Atlantic passenger steamers, owing to the rivalry of certain companies, each being determined to have the fastest vessels in the trade.

Mr. John, in his able paper on "Atlantic Steamers," read before the Institution of Naval Architects in July last year, went very fully into this question, but there is already something to be added to what he said, for considerable advances are now being made upon what had then been done, not only in the speed, but also in the means by which that speed is to be attained. Mr. John used these words, "People are asking what the next change is to be. I think everyone is agreed that triple expansion engines are inevitable, and I think there is also a tendency towards twin screws. Forced draught I am not so sure about at present." Now, those words were only written last year, and the "Umbria" and "Etruria" were then, and are now, the fastest mercantile vessels afloat; they have compound engines, single screw, and no forced draught.

But we have now building on the Clyde two vessels for the Inman and International Company, and at Belfast two for the White Star Company, which are expected to be far in advance of those.

The new vessels are to have triple expansion engines, twin screws, and forced draught—three very important steps forward, and steps which

have not been taken without very serious thought and consideration, especially, I expect, upon the forced draught question. The other main differences are:—

	Length.	Breadth.	Depth.	Gross Tonnage.	I.H.P.	Speed. Knots.
"Umbria" and "Etruria"	500	57	38	7,718	13,500	18
New vessels	550	62	39½	9,000	20,000 to 22,000	22

The differences are striking, and if expectations are fulfilled, these vessels will be by far the finest mercantile steamers afloat.

This subject is so interesting, and the various points raised so important, that I regret that I can do no more than make this brief reference to it this evening, but I hope that the subject will be taken up by abler hands than mine, and dealt with fully in a paper for this Institution at an early date.

Now, as there are some similar vessels to be built at once for another company, shall I be out of place in expressing a hope that the contract may fall into the hands of an East Coast firm? I heartily hope that it may, for if it does I am sure that the owners need not fear the result, and the interest in the Atlantic competition will not be lessened, but considerably increased, if the vessels for the three competing companies are built in England, Scotland, and Ireland respectively.

Gentlemen, it is very difficult for one in my position to tell such an audience as this anything entirely new, and I hope that you did not expect it. All one can do is to make a brief reference to such questions of the day as are likely to be of interest, and to combine the historical with the suggestive. I hope I have in some slight degree been successful in my attempt.

The Earl of Ravensworth said, he had been asked to undertake a duty which was in itself a very simple one, but, he could assure them, to him a most gratifying one; that was, to ask them to give what he was quite sure would be a unanimous vote of thanks to their excellent President for his most admirable, practical, and useful address. He did not come there expecting, amongst an audience of thoroughly practical and skilled men, to make a speech, and he was quite sure that if he were to attempt to address himself in a critical sense to such a paper as this, written with all the care, all the knowledge, and all the resources at the disposal of their President, they would consider it, as he should consider

it, an act of the greatest presumption. He (Lord Ravensworth) questioned even whether the most practical man in that hall would, on the spur of the moment, attempt to address, in a critical sense, observations upon a paper such as that submitted, and therefore he would content himself with making one or two very short remarks, asking them, when he sat down, to return to Mr. Doxford their thanks for his address. There was one feature in the paper which to him, a Tynesider, and to all of them who were Tynesiders, was a very gratifying one, and that was the very large amount of work in the shape of conversion of the old compound engine to the triple expansion engine that had fallen to the lot of the Tyne to perform. That was very gratifying. On the North-East Coast 43 vessels had been altered, that was, in the conversion of the engines, as against 17 on the part of their great rival, the Clyde; 14 on the Mersey, and only 4 at Aberdeen. He thought that must be satisfactory, as the President had remarked, to the members of this Institution. Well, there was one more point—as the President had done him the honour to bring in his very humble name there—to which he would just advert for a moment. He (Lord Ravensworth) stood corrected, and he was always glad to stand corrected. He was always glad to stand corrected by men who knew very much more about the subject than he could pretend to do; but he would also take leave to observe that there were very important reservations even in his excellent friend's criticism, because he had told them although his (Lord Ravensworth's) words were not strictly accurate at the present moment, they might become true at any moment unless they took care of themselves; and it was rather remarkable, and he did not think it was altogether highly satisfactory even to their excellent President himself, a shipbuilder, to be told that if they intended to keep up their position as the leading shipbuilders of the world, they must keep down their prices. He should like this observation to go forth to their working men, to those engaged in the great industry of shipbuilding, if they desired to maintain the lead in it they must keep their prices down, that being the only way in which they could keep other countries in check and retain the bulk of the trade in their hands. Now, he did hope and trust that the intelligent working men in this country would take these words to heart, because they knew perfectly well when these unhappy differences—these strikes—took place, the orders went away, and it was very much easier to lose orders than to regain them; they had also the authority of a thoroughly practical man to tell them that their only chance of retaining their leading position as shipbuilders was to keep down their prices; and therefore when the demands

for increase of wages were made and strikes ensued, depend upon it they were in great danger of losing that position which they had obtained by their industry, their energy, and their enterprise. Now, he did not wish to detain them longer, but he did wish to be allowed to say one or two words of thanks, cordial, heartfelt thanks, and he was happy to see, and he was sure they shared his happiness to see sitting beside him one of their honorary members, whose presence that night was as agreeable to him as it was unexpected—his distinguished and esteemed friend, Mr. White, no less a man than the chief constructor of the Navy. They both, he was quite sure, came there very much with the same motive, to express by their presence, representing as they did the leading institution in London—the Institute of Naval Architects and Marine Engineers—he was quite sure, without having had a word of conference with him upon the subject, that they came there very largely with the hope of expressing by their presence their thanks to the North-East Coast Institution of Shipbuilders and Engineers, their cordial thanks, for their reception of them this year, for enabling them to judge of the gigantic resources of this and neighbouring rivers, for the hospitality that they extended to them, the kindness with which they were received, and the extreme pleasure and the extreme amount of instruction and amusement that they had derived from their visit. Representing, as he had the honour of doing, the Institute of Naval Architects in London, he had the greatest pleasure, on this their annual meeting, of returning to their excellent President—and he was delighted to hear, in passing, that they had had the advantage of securing him for another year as their President, a more practical and better President he thought they might have had considerable difficulty in obtaining, and he congratulated them all upon his re-election—and to them, one and all, his hearty thanks for the pleasant memories that the Institute of Naval Architects and Marine Engineers would ever retain of their late visit to the Tyne. With these very few words, he begged to move—that which he was quite sure would be accepted without a dissentient voice—a vote of thanks to their excellent President for his most admirable, practical, and useful address.

Mr. A. Coote said, he had been asked to second this vote of thanks, and he did not hesitate to state that he rose to do so with considerable pleasure. He wished it had been entrusted to better hands, but having been entrusted to him he could only say that he was very glad to have had the pleasure of hearing Mr. Doxford's paper, and very proud to follow Lord Ravensworth in asking them to give to the President a most hearty vote of thanks. He felt sure that all Mr. Doxford had done since he

assumed the responsible position of President of this Institution had commended itself to them all. This had been—they would agree with him—an eventful year to their Institution. It was a difficult task their first President had undertaken, but his duties had been well performed, and they were all very proud of him. After his second year had passed, some of them began to think it would be rather a hard task for him who had to follow. They looked about somewhat tremulously to see if they could get any one to come boldly forward to fill a position which had been so well occupied during the two first years, and now they could congratulate themselves on having had such an able successor to Mr. Boyd. As they had now started on this second period of the Institution's existence they might hope for better things in the future, and being practically established, they need no longer fear but that there would be many others to follow those they had been so fortunate in obtaining up to the present. The past year had been an historic year in more respects than one. They had had the London Institution of Naval Architects in this district, and, as Lord Ravensworth had mentioned, they had to thank their President very considerably for the amount of success which had attended their visit. By his intelligence and energy the whole proceedings were carried to a most successful issue, and this was, he believed, the unanimous opinion of all interested in the matter. Mr. Doxford had also taken a great interest in the proposed formation of a Chair of Naval Architecture. He was sure they were indebted to him for this, and as he (the President) had hinted that the matter would go forward, he (Mr. Coote) felt certain that as their President had some scheme maturing which he would lay before them, they would at the first sound come up as strong as they possibly could to support him. He (Mr. Coote) did not see quite clearly the way, but they would all be prepared to follow the President's lead. In regard to the actual scope of his address, he should be very sorry indeed on the spur of the moment to attempt to analyse it. As far as he could judge of it, however, he thought it would be very difficult indeed for any of them to have prepared a more intelligent or a more satisfactory *resumé* of our present position. When they read the address of the President last year they all felt it was a special effort, something new, and it was highly appreciated by all who heard it, and by many who, perhaps, had read papers of this description before. We imagined it would be found difficult to contribute a second paper on a subject which appeared to have been then so comprehensively treated, yet to-night our President had excelled his former effort, and they might now be inclined to think that he was far from being exhausted and

well worthy their consideration as to whether they should not try to get him to give them yet another paper. He (Mr. Coote) was sure they were all glad that the President had still some hope for our somewhat depressed industry. As a shipbuilder, he could sympathise with him in desiring a better state of things. He had some hope that America might, perhaps, want ships, and there were one or two other points which were reassuring and indicative to some extent that the depression was over. The remark as to the means by which this industry could be kept going, and to which Lord Ravensworth alluded, was not very encouraging, namely, that they must keep down the prices. It was very difficult for them to find out exactly how this was still further to be done, as they had already cut down to a tremendous extent and it had not done them very much good of late. Of course there was a great deal of truth at the bottom of what the President said, they had to meet all comers, and therefore everything must be done to keep themselves to the front and overcome that foreign competition which seems, at all events, looming in the future. One way of doing it, no doubt, was that of paring down the actual cost in every possible way. The only fear was that this could not be done without interfering with the efficiency of the work produced, and in this district their very existence depended on keeping up, or rather attaining to a higher standard of workmanship and to a higher class of vessel. To keep down the prices, therefore, in that view, might be the most likely way to defeat the end they had in view, which was to keep the front rank in producing work second to none other in the kingdom. He re-echoed the hope of the President, that some of the large vessels to be built for the Atlantic might come their way, and that this North-East Coast of theirs would stand equal to any in the construction of first-class vessels in the future. He had very great pleasure in seconding the resolution.

Lord Ravensworth put the resolution to the meeting and it was agreed to by acclamation.

The President thanked his Lordship and Mr. Coote for the very flattering manner in which they had referred to himself, in a much more flattering way than he felt he at all deserved. He had, of course, in the past done what he promised to do when he entered upon the duties, and for the incoming year he would continue to do the best he could. Unfortunately, in regard to his paper, there had been so far practically no opposition to what he said, so that he had no chance of making any reply. There was one point which, perhaps, they had put a little stronger than he intended it to be, and that was, both his Lordship and Mr. Coote put it that "the prices must be kept down." The words he used were—

"as soon as the tendency for prices became excessive it would be dangerous." He (the President) thought there was plenty of room for a moderate advance in the price of steamers without danger, but not to the prices we had four or five years ago. He must thank them for the way in which they had received the proposal made by his Lordship. If any other gentleman wished to make any remarks upon the address he thought there was plenty of time to hear what he had to say.

Mr. W. H. WHITE, responding to a request to speak, said he did not think it was quite fair for visitors to monopolise all the talk on such an occasion as this; but he could not refrain from saying a word or two, although he was not going to attack the President's figures, or in any way challenge his position. He thought all who had anything to do with the commencement of this Institution, must feel that their hopes had been much more than fulfilled. He had known something of the origin and working of institutions of this kind; but, so far as he knew, there never had been an institution of this nature that had in so rapid and thorough a fashion attained equal success. Not long ago he was speaking with a friend, a shipbuilder on the Clyde, who had sought membership of this Institution, and said he had done so on this simple and reasonable ground, that he found in the proceedings of this Institution much that was worthy of one in authority to make note of and use in his work. That was a statement made by a man of great ability and large experience on the Clyde, and he (Mr. White) thought that it was one of the best testimonials that could be given of the merit of the papers and the discussions which had taken place at the meetings of this Institution. He could only say himself that—although he was now away from Newcastle, thanks to the honour they had done him in making him an honorary member after he left—he was always glad to receive, and made a point of reading the proceedings, and if only the standard of excellence which had been attained in the past could be maintained in the future, then this Institution must flourish. The question of finance which he heard one gentleman raising, when he (Mr. White) came in, somewhat late, was, no doubt, one requiring attention; but when they had reached a membership of over 500 in something like two or three years, he thought and most earnestly hoped that the question of finance would never be one of any difficulty, or in any way capable of injuriously affecting the future of the Institution. In a paper of his own, which he thought was the first read in connection with this Institution, he ventured to say that he hoped one result of the founding of the Institution would be the encouragement of the undertaking of work of a higher and

more varied character than had hitherto been the custom on the North-East Coast. In the discussion which followed, his excellent friend, Mr. Coote, rebuked him, saying, with great force, that gentlemen who were connected with private industry naturally thought of the commercial side of their work, and as long as the staple product of the North-East Coast could be depended upon, so long was it good to stick to the staple of the North-East Coast. He (Mr. White) fully admitted the force of Mr. Coote's remarks, but he could not help thinking when he heard Mr. Coote's speech just now, that "sweet are the uses of adversity." Mr. Coote had become a complete convert to the view he (Mr. White) put forward in 1884, and no one could walk through the Exhibition and look at the models, not of the projects only, but of vessels that had been built and done their work, without seeing that the last three or four years had produced a wonderful result on this North-East Coast in the types of vessels undertaken and the results achieved. To that success and development of industry in this district, he was confident the founding and existence of this Institution had largely contributed. He should like to say one or two words about the points raised in this paper in connection with the increase of speed and mechanical propulsion of steam ships. Now, Mr. Doxford had very properly drawn attention to the influence of forced draught and of increased piston speed; but there was something beyond that as Mr. Doxford well knew, something to which Mr. Hall in his paper, he believed, also made allusion, and of which Mr. Hall certainly had intimate personal experience, namely, that the savings of weight which had been attained in war ships' machinery, were largely due to the use of more costly material and the introduction of a large amount of additional work in machinery, and otherwise disposing of the material which was in the engines to do the work with the best association of lightness with strength. He was bound to say that acquaintance with the engine rooms of cargo steamers and many other merchantmen satisfied him that that condition had not always been fulfilled. He thought if the President would be good enough to consider that remark he would find a very great source of advantage, in addition to the question of piston speeds and forced draughts which affected, of course, the weight of the material in regard to the production and use of steam. A somewhat increased first cost must of course be faced. The other point to which he would refer before sitting down was the question of labour. He knew it was the fashion for those who largely controlled the opinion of working men to say that those who had the management of business always wanted to begin the economies at the wages end; but

facts had come to his knowledge in the production of war ships and torpedo vessels abroad, in Germany more particularly, which should be known by the working men, the shipbuilders of England. He (Mr. White) knew as a matter of fact, not opinion at all, that the outlay on labour on that class of vessel in Germany was from 20 to 30 per cent. less than the corresponding outlay here, the result of which was that although English builders had never failed on vessels of certain dimensions to achieve results in point of speed surpassing those reached abroad, they could not compete in point of cost if speed and other conditions were fixed. He dared say, what was true of that special class was true to some extent in other classes, and if on the labour side there was that enormous advantage he did not see how competition could be fairly conducted or how the prices could be kept down without an appeal to the wage-earning class to assist in reducing the cost of production. He had no wish to enter into any controversial matter—but the labour question was inevitably mixed up with this foreign competition, and all that could be supposed was that as foreign countries advanced in their shipbuilding they were likely to grow up into conditions similar to those which had to be faced here, and further, it was to be hoped that the working people here would come to realise that their interests were very much mixed up in the cheapening of price which the President looked upon as inevitable if the lead was to be kept.

Mr. J. P. HALL wished to draw attention to the President's remarks on page 17, which read as follows:—"We further find that no country in the world, except the United Kingdom, is at present able to supply a market outside of itself, and that, therefore, with the exception of the four countries named, the whole world is dependent upon the shipbuilding yards of this country for its fleets." Now he (Mr. Hall) thought it was scarcely the exact state of affairs. He had recently been to Germany, and found that they had got a very large productive power. They have a large yard at Stettin, an extensive place at Kiel, and two or three building yards at Hamburg, of large capability in producing. Taking the figures as given on page 16, it will be seen that the total tonnage produced and ordered outside by the Germans only amounted to about 61,000 tons. This, he said, was simply the product of one of the many large establishments on the North-East Coast here. But he was of opinion that the Germans were capable of doing three times the amount of what has still been reported as received into their fleet. He would also like to draw attention to the statement on page 16 that the French had only built and received a total of 18,000 tons of shipping. He considered

they also might do two or three times as much as they do now. He thought we must not run away with the idea that we were the only shipbuilders in the world, as Germany and other countries were severe competitors, and, doubtless, in the course of two or three years, by the extensions they were now making, would be able to produce much more extensively, and we should certainly feel the force of their competition at an early date.

Mr. C. W. HUTCHINSON said, that perhaps Mr. Hall might be carried away by visiting a yard or two; and, perhaps, seeing interesting things abroad gave them more importance than they really deserved. He thought that the figures in the columns to which Mr. Hall had referred would support some slight criticism upon his remarks. If Germany had built for her elsewhere than in her own country 16,942 tons, she was far from supplying her own demands. But the point he wished to refer to was that the yards of Germany were occupied to some extent in building war vessels, and did not come so very much into competition with us in building merchant vessels, and he thought the rate of progress likely to take place both in Germany and France was not such as to enable them rapidly to overtake their own demands, nor to enter into serious competition with us in the supplies pointed out in the paper.

The PRESIDENT said, before closing the meeting he would like to refer to what Mr. White said as regarded the reduced weights. He (the President) thought that the reduced weights might be got by improved material, and he included in "improved material" a better class of workmanship; but for mercantile ships the extreme reduction made in the weight of machinery of war vessels was neither necessary nor desirable, even if the extra cost did not put it out of the question. He was very sorry to hear what Mr. White said about the labour on the Continent being 20 to 30 per cent. less than paid in England.

Mr. WHITE—I was speaking of a particular class of vessel. I don't say it is true of mercantile vessels.

The PRESIDENT said, he thought that Mr. White's remarks referred to the cost of labour upon all vessels.

Mr. WHITE said, he spoke of torpedo vessels merely, and small swift craft of that kind. As a matter of fact he knew that in vessels which had been compared the cost of labour was from 25 to 30 per cent. less than it would have been on corresponding vessels in England.

The PRESIDENT was sorry at that, for the reason must be that the men were working at much lower rates.

Mr. WHITE—That is so, and longer hours.

The PRESIDENT said, there was no disposition on the part of builders here to reduce the wages any lower than they were at present if they could possibly avoid doing so, and they could only hope that they would go up on the Continent, so as to equalise the cost.

Mr. WHITE begged them not to think for a moment that he expressed any opinion as to whether the wages were too high here or not; he only said if that was the difference then clearly competition was not being conducted here under conditions which could be successful.

The PRESIDENT said, he thought they would all agree there was a great deal in what Mr. White said, and they must fight it out as best they could. Mr. Hall did not quite agree with some of the figures he gave, but Mr. Hutchinson had, to a certain extent, answered Mr. Hall. He could not himself quite see how Germany could be building, so far as merchant vessels were concerned, many for other countries, for, with the exception of Spain, he thought he had dealt with all the countries that were building or buying mercantile vessels of any moment.

Mr. HALL—War vessels for other countries.

The PRESIDENT—Of course, if the German yards were building war vessels for other countries to any considerable extent they were competing with us very seriously in a class of work which we had hitherto thought peculiarly our own. Before sitting down, he thought they would agree with him in thanking Lord Ravensworth for his presence there that night. It was the first time they had had his Lordship present amongst them at these meetings; and, although he did not profess to be a practical man, whenever he did speak he always said something well worthy of hearing. It would be hoping too much to expect his Lordship often at their meetings, but if they could see him now and then, when in that neighbourhood, he was sure they would agree with him when he said they would be most delighted to see him present.

LORD RAVENSWORTH thanked them very gratefully and very heartily for the kind expression they had given for his presence that evening. He begged to repeat that he had two special objects in coming there that night, and he hoped that the reception he had received would be an encouragement for him to attend oftener at their meetings. But the two special reasons why he came to their annual meeting was, first of all, as representing the Institute of Naval Architects, to thank them all for their reception of them that year, and, secondly, and still more, to convey to them the very deep and lasting interest which he took in this particular branch Institution. He had watched it from its formation, and he ventured to think that no institution had ever grown with more rapid proportions,

and had exhibited by the papers that had been read there and discussions that had ensued upon those papers, a larger amount of practical, useful knowledge than the papers that had been read by the members of this Institution. Of course it went without saying that on the banks of the Tyne a school of naval architecture and marine engineering was an absolute vital necessity; and he congratulated his friend Mr. White, who was an active promoter of this very valuable Institution, and congratulated Mr. Doxford and all of them in the progress they had made, shown by their numbers, something like 600 members. He ventured to say, almost to challenge, any kindred institution to have done so much useful work and to have made such progress in so short a time as the Institution of Shipbuilders and Marine Engineers on the banks of the Tyne. He congratulated them most cordially, and wished them to bear in mind that the least he could do in return for the honour they had paid him, a most unworthy and unscientific man, in electing him an honorary member of this Institution—an honour of which he was exceedingly proud—was to take a deep concern in its rise and progress.

This concluded the business of the meeting.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887-88.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LIBRARY, FAWCETT STREET, SUNDERLAND, ON WEDNESDAY EVENING, NOVEMBER 16TH, 1887.

ARTHUR COOTE, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last Annual Meeting, held in Newcastle-upon-Tyne on October 19th, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. F. J. Trewent and R. S. White to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Bramwell, Balfour, University College, London, W.C. (late Graduate).
Cannell, Frank, H. Parry & Son, Lisbon.
Douie, Andrew, 73, Park Road, Newcastle.
Hill, Maxwell, Germania Werft Gaarden bei Kiel, Germany.
Jones, Morlais G., 108, Andrew's Crescent, Cardiff.
Macarthy, Harry, Ashfield House, Newcastle.
Niven, William A., 82, Jackson Street, North Shields.
Panton, W. H., Stockton Forge, Stockton-on-Tees.

ASSOCIATES.

Jenkins, William, Consett Hall, Blackhill, Co. Durham.
Panton, Hugh, 38, Fawcett Street, Sunderland.

GRADUATES.

Boyd, William, junior, North House, Long Benton.
Foley, Wm. C Le B., 26, Ashfield Terrace West, Newcastle.
Head, Alston G., 3, Cambridge Road, West Hartlepool.
Rendel, Henry W., 120, Park Road, Newcastle.
Ritson, Stanley W., 18, St. Bede's Terrace, Sunderland.
Windham, Harry S., 3, Cambridge Road, West Hartlepool.

The following papers were then read and discussed:—1. "Notes on Steamship Speed Calculations," by Mr. G. N. Arnison, Junior. 2. "The Influence of Coal Consumption on the Commercial Efficiency and the Design of Cargo Steamers," by Mr. Robert Thompson.

NOTE.—*Mr. Thompson's paper was read first at the meeting, but owing to the discussion on it having been adjourned, and that on Mr. Arnison's paper closed, I have placed the latter first in the Transactions.*—EDITOR.

NOTES ON STEAMSHIP SPEED CALCULATIONS.

By GEO. N. ARNISON, Jun.

[Read before the Institution, November 16th, 1887.]

It is not purposed in these notes to attempt to review the entire subject of Steamship Speed Calculations, but to indicate one or two points of interest that have arisen in the writer's own immediate experience. Some references will have to be made to eminent authorities, but the scope of these notes must be necessarily limited; for, instead of a few pages, a volume might be easily compiled, were it attempted with any degree of completeness, to review even the various formulæ that have from time to time been in use, or to consider even a moiety of what has been advanced on the subject of steamship speed efficiency. Nevertheless it is hoped that these notes will be partially interesting. Probably they would not now have been compiled had not (in the discussion on Mr. J. P. Hall's paper on "Compound *v.* Triple Expansion Engines from a Shipowner's point of view," read last session,) doubts been thrown upon the advisability of using the coefficient of speed efficiency, expressed thus:—

$$C = \frac{V^3 D^{\frac{2}{3}}}{I.H.P.},$$

and had not, inferentially, preference been shown to formulæ based upon the "immersed area of midship section" and the "wetted surface."

Another reason that has actuated the writer in compiling these brief notes, is that there is a tendency to discount results obtained from actual practice in favour of those obtained experimentally. No one is, however, more ready than the writer to acknowledge the benefits obtained by experiment. The late Mr. W. Froude, F.R.S., may be specially mentioned as having, by carefully conducted ship-model trials, achieved praiseworthy results, which emphasised the necessity of screw steamers having long and easy "runs." This necessity had been partially but inadequately indicated by the late Mr. John Scott Russell.

Mr. Froude also demonstrated that when steamers are driven at a higher speed than that they are adapted for by their dimensions and form, the resistance is in excess of that corresponding to the cube

root of the square of the displacement, and the power increases at a higher rate than the cube of the speed.

Although theoretical or experimental research has done good work, it does not follow that results obtained in actual practice are not equally valuable; and when it is remembered how few are the opportunities of taking part in "tank experiments," and how many, comparatively, are the opportunities (more especially since there is locally a measured mile) for acquiring data from the trials of actual steamers, the utilisation of these latter results is all important; and the writer has yet to learn that there is a better method of gauging actual results than by the adoption of the speed coefficient expressed by $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.}$, or, in special cases, that expression as modified by Mr. Robert Mansel.

Again, even though shipbuilders on the North-East Coast were, either individually or conjointly, to incur the cost of experimenting with ship models, in order to ascertain the most suitable form of hull, the instances would be few in ordinary mercantile shipping in which any benefit in practice would accrue. It would only be in an exceptional case, that the shipbuilder would delay commencing the work of construction, awaiting the results of comparative ship-model trials. Further, in many cases the shipbuilder has only, if at all, *carte blanche* in fixing the dimensions of a steamer, or of altering those suggested by the shipowner, so far as, in doing so, the scantlings of the hull and, therefore, its weight will not be increased. There are many other considerations which affect the fixing of dimensions, which, however, need not be mentioned.

What is wanted is that reliable data derived from actual practice should, as far as possible, be made public. Carefully ascertained actual results in practice can scarcely be so liable to mislead as those obtained by experiments. There are, with experimental data, uncertain allowances to make, viz., for the efficiency of the propeller, friction of the machinery, etc.

Theory has sometimes proved to be misleading. Twenty-five years ago, and probably in some quarters even more recently, the resistance of a vessel was supposed to be largely in ratio to the immersed area of the midship section, and steamers were built of narrow beam, great proportionate length, with the midship section having great rise of floor, and with bilges of easy curve. Again, the fore-body, or "entrance," *i.e.*, the part of the ship bounded by the stem, and the foremost athwartship section, which has the full dimensions of the midship section, was kept much longer than the after-body, or "run." The fore-body lines were frequently hollow and so fine that there was as much, if not more, dead-

wood forward than aft. Practice in this respect is now altered, and the "entrance" and "run" made about the same length, the latter being not unusually longer and finer than the former. Excessively fine fore-body lines, so common in the early steamers, made these vessels in nautical phraseology very "wet," causing them to plunge their heads into the seas; and, doubtless, this has to some extent been the cause of fuller fore-body lines being adopted. Early theory was, however, to blame for the excessively fine fore-body lines, and, in particular, the "wave line" theory, which was based upon the speed of trochoidal waves. This, as expounded by the late Mr. John Scott Russell, required longer "entrances" than "runs;" and the speed calculations of the late Professor W. J. Macquorn Rankine pre-supposed that the steamer for which the propelling power was to be computed, complied with the rules for lengths of "runs" and "entrances" laid down by the late Mr. John Scott Russell, which for convenience of reference it may be as well to quote. They are as follows:—Let V be the "maximum speed of the ship" (in knots per hour), L_1 be the length of "entrance" appropriate to the speed V, and L_2 the length of "run" (both lengths being expressed in feet), then—

$$L_1 = 0{\cdot}5625 \times V^2.$$

$$L_2 = 0{\cdot}375 \times V^2 = \tfrac{2}{3} L_1.$$

Let us see, then, for example, what length of "run" and "entrance" is required by this rule to avoid undue wave-making, in the case of a steamer of a speed of 20 knots:—

Length of "entrance" $= 0{\cdot}5625 \times 20^2 = 225$ ft.

Do. "run" $= 0{\cdot}375 \times 20^2 = 150$ ft.

It will be here noticed that the length of "run" is only two-thirds that of the "entrance;" and the writer takes the opportunity of expressing the opinion, that while such proportions may be suitable for paddle steamers, for screw-propelled vessels he would rather reverse the proportions. As far back as 1866, the late Professor Rankine stated that, so far as he had "been able to gather from the performance of actual steamers, the additional resistance produced by deficiency of length in the fore-body is not nearly so marked or so great as that produced by deficiency of length in the after-body; so long, at all events, as the fore-body is not less than two-thirds of the length given by the rule (that is, equal to the after-body)."

This brings the writer to notice the rule of computing the propelling power and speed laid down in *Shipbuilding: Theoretical and Practical*, edited by the late Professor W. J. Macquorn Rankine, C.E., LL.D., etc. There must always be, in estimating the indicated horse-power necessary to propel a steam vessel at a given speed, some degree of approximation.

What is wanted is that the system of estimating used should, with the minimum of work, have a maximum of reliability. This certainly cannot be claimed for the augmented surface system, and, further, a great drawback to its use is, that it requires quantities which can only be positively ascertained after the design of the vessel is complete. Doubtless "wetted surfaces," the angles of obliquity of entrances, can be assumed by those experienced in using this rule, but the more assumptions there are the greater the probability of error. Again, in fixing the coefficient of augmentation, the ordinary "augmented surface" rule entirely disregards the character of the "run," so that it cannot be claimed that it takes into account, apart from a varying coefficient of propulsion, all the important factors in speed calculations.

Professor Rankine's rule for computing the probable indicated horse-power required for a steam vessel is tolerably well known; but it may be well to quote it, viz., "Multiply the augmented surface in square feet by the cube of the speed in knots, and divide by 20,000, the quotient will be the probable indicated horse-power."

It may also be important to note how the augmented surface is obtained. First, the area of the immersed or "wetted" surface is calculated, and that area is multiplied by the coefficient of augmentation. The latter is obtained by multiplying by 4 the square of the sine of the mean angle of obliquity of the fore-body, added to the fourth power of the sine of obliquity, added to unity.

Taking for an example a paddle steamer whose engines indicated 1,040 horse-power, the following calculation was made to ascertain what speed should be obtained by that power :—

First, the area of immersed body was obtained by ascertaining by careful measurement the half girths at intervals of 12 feet, then, by Simpson's rule, the mean half girth was calculated. This was found to be 9·1 feet without the keel, or 9·49 feet actual mean half immersed girth, which, multiplied by the length on the load water-line, gave 1,840 feet as the half immersed area, or 3,680 feet total immersed area. The coefficient of augmentation was calculated as follows :—

Water-Line.	Sine of Obliquity.	Square of Sine.	Fourth power of Sine.
3 ft. 6 in.	·160	·0256	·0006
2 ft. 11 in.	·159	·0252	·0006
2 ft. 4 in.	·153	·0234	·0005
1 ft. 9 in.	·145	·0210	·0004
1 ft. 2 in.	·137	·0187	·0003
7 in.	·108	·0116	·0001
	Means	·0210	·0004

These means might have been reduced by including the keel sine of obliquity as 0·0; but it was not done, as the actual draught of water slightly exceeded the designed draught of water, and the error, if any, was on the safe side. The immersed area was taken to the actual draught of water.

The coefficient of augmentation was thus—

$$1 + (4 \times \cdot 0210) + \cdot 0004 = 1 \cdot 0844.$$

Now, multiplying the immersed surface 3,680 feet by the coefficient of augmentation 1·0844, we have the resultant, 3,990, as the augmented surface.

Reversing the rule (already quoted) for obtaining the probable indicated horse-power, so as to arrive at the probable speed, we have—

$$\frac{\text{I.H.P. } 1{,}040 \times \text{constant } 20{,}000}{3{,}990 \text{ augmented surface}} = \frac{20{,}800{,}000}{3{,}990} = 5{,}213 \cdot 03,$$

the cube of probable speed. Extracting the cube root of 5,213·03, we have 17·3 knots as the probable speed.

In this instance the actual speed was 16·44 knots, but the calculation already given was not that on which the indicated horse-power of the engines was decided. The calculation was made to test the value of Professor Rankine's rule, and the result was not deemed very unsatisfactory, seeing the lengths of the "run" and "entrance" were below that required by the "wave-line" theory for the probable and the actual speed. It may be here stated that the writer has subsequently become aware of a provisional rule of Professor Rankine's for the additional resistance due to a short after-body, which will be found in foot-notes to pages 248 and 249 of *Shipbuilding: Theoretical and Practical,* of which Professor Rankine was the editor.

The instances which destroyed the writer's confidence in the "augmented surface" rule were as follows:—Two well-designed fine-lined screw steamers, D and E, 225 feet long, by the speed rule in question, were found to require 953 indicated horse-power for a speed of 13·21 knots, on a displacement of 980 tons, while 1,231 indicated horse-power was actually exerted in the case of D; so that, to make "practice" square with "theory," the constant of 20,000 should be 15,485. Possibly part of the discrepancy is accounted for by the vessel's propeller not having been entirely immersed, more especially as the sister vessel E, loaded somewhat deeper, attained a slightly higher speed, viz., 13·4 knots per hour, with 1,209 indicated horse-power; *but even these latter figures show a discrepancy of upwards of 10 per cent. between the estimated and the actual indicated horse-power.*

The attention of the writer was soon afterwards directed to a sliding

scale, designed by Mr. Robert Mansel, the well-known Clyde shipbuilder, by which probable speeds and powers could be rapidly obtained, when using either the coefficient expressed by $\frac{V^3 \ D^{\frac{2}{3}}}{I.H.P.}$ or $\frac{V^3 \times \square'}{I.H.P.}$.

A table was compiled of authentic trial trip results, containing the dimensions, tonnage, displacement, coefficient of displacement, area of midship section to load-line, speed, horse-power, etc., which is partially reproduced in Table I. For permission to publish this data the writer is indebted to the firm of Messrs. David and William Henderson & Co., Glasgow, as well as for data previously quoted.

In Table II. are given the results of six large steamers' regular trading for the year, in the case of every item the mean results being given.

TABLE I.

		Displacement in Tons.	Coefficient of Displacement.	Area of Midship Section.	Coefficients of Speed Efficiency. $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.}$	Coefficients of Speed Efficiency. $\frac{V^3 \times \square'}{I.H.P.}$	Speed in Knots.	I.H.P.
A	Screw Steamer	820	·551	197	226	510	11·85	650
B	Do.	890	·654	239	220	562	10·00	420
C	Do.	994	·549	268	192	516	12·3	960
D	Do.	980	·547	252	186	472	13·21	1,231
E	Do.	1,095	·560	277	207	540	13·4	1,209
F	Paddle Steamer	240	·571	69	163	298	16·44	1,043

TABLE II.

G	Screw Steamer	8,610	·637	856	247·0	502	14·05	4,720
H	Do.	7,341	·610	847	240·6	539	13·55	3,904
I	Do.	7,206	·622	840	231·0	520	13·42	3,900
J	Do.	6,847	·640	828	229·6	627	12·05	2,310
K	Do.	5,916	·613	794	229·8	558	12·94	3,081
L	Do.	5,703	·668	730	208·9	477	12·35	2,879

The sliding scale already alluded to proved of limited use, as it only extended to 2,500 indicated horse-power and 5,000 tons displacement. It was at one time the writer's intention to have constructed a larger one, but as by the use of logarithms, calculations for individual cases could be rapidly made, the idea was abandoned.

Examining Table I., it will be seen that the coefficients of efficiency of displacement vary from 163 to 226, showing a difference of 38·6 per cent.; while the corresponding coefficients of the immersed areas of midship sections vary from 298 to 562, showing a difference of 88·5 per cent. Similarly in Table II. the displacement coefficients vary from 208·09 to 247, showing a difference of 18·23 per cent.; and the corresponding coefficients of the immersed areas of midship sections vary from 477 to 627, showing a difference of 31·4 per cent. Attention is called to these variations. The difference in the percentages in Table I. being 49·9 per cent., and Table II. 13·17 per cent. It need scarcely be urged at the present time that speed calculations, based solely or mainly on the immersed area of the midship section, must be very unreliable, and attention is directed to the screw steamers G and H in Table II. These steamers have the same form and dimensions of midship section, the increased area in the case of G being due to slightly greater draught of water. The larger displacement of G is due to that vessel's greater length. Now, although we see that G is a more efficient vessel as regards speed, according to the coefficient of efficiency of the displacement, yet if the indicated horse-power had been based upon the coefficient of efficiency of a midship section area of H, only 4,393 indicated horse-power would have been provided, and the speed of the vessel with that indicated horse-power would have been only 13·72 knots, a deficiency of ·33 knot, while if the vessel G had only had the speed efficiency of H, the speed would have only been 13·6 knots, a deficiency of ·45 knot. Now by using the speed efficiency coefficient of displacement of H to ascertain the indicated horse-power required to drive the larger vessel G half a knot faster than H, an error on the safe side occurs, 4,829 indicated horse-power being then the probable power. Such cases as these might be easily multiplied, and even more glaring ones instanced, as those quoted have not been for the special purpose of demonstrating the vagaries of the coefficients of speed efficiency of midship section areas.

The writer would offer a possible explanation of the low coefficients for the vessels C, D, and F, which are very marked as compared with vessels G to K. The first-mentioned vessels are of light displacements, while the latter are of heavy displacements. As regards L, it may be remarked that this vessel was originally designed for a considerably less draught of water than that on which the results in Table II. were obtained; and the design, as partially evidenced by the comparatively high coefficient of displacement, ·668, was not suited to the speed at which the vessel was driven, more especially as regards the after-body lines.

In closing these notes, the writer would briefly allude to the results of varying weather and condition of the bottom of a steamer as affecting speed efficiency. A steamer on her first voyage had very bad weather, and the speed efficiency coefficient of displacement was 209. On the second voyage the vessel had bad weather outwards, but made a good homeward passage, resulting in a coefficient of 234·6. On the third voyage there was moderate weather on the outward passage and fair weather homeward; again the coefficient increased, viz., to 255·2. Two days' bad weather outwards on the fourth voyage was apparently the cause of the coefficient falling to 246·9. On the fifth voyage, although moderate weather prevailed outwards and fair weather homewards, the coefficient fell to 232·9; probably by this time the bottom was somewhat foul. The mean speed efficiency coefficient of displacement for the five voyages was 235·7.

DISCUSSION.

Mr. Alex. Adamson said, he thought Mr. Arnison deserved their thanks for the paper. He did not claim to put anything new before them, but he (Mr. Adamson) must say that he put one or two things in rather a new light to him, and in a light which he could not altogether pass without taking notice of. In one part of the paper he said he had had his confidence destroyed in the coefficient for calculating speed in which the augmented surface forms one of the terms. In another part he pinned his faith to the coefficient in which the square of the cube root of the displacement is used instead of the augmented surface. He had always understood that these coefficients varied in the same proportion in any vessel for the same speed. In fact, this could not be otherwise, when they considered the fact which the writer of the paper must have overlooked, that the displacement coefficient was based on the augmented surface, the augmented surface of vessels of similar form being nearly in proportion to the square of the cube root of the displacements. The square of the cube root of the displacement and augmented surface may, therefore, be called synonymous terms. In comparing these coefficients for any vessel it would be found that they varied in proportion. If they had a high coefficient by the augmented surface method they would find a correspondingly high one by the displacement method, and if the one coefficient is found to be low in any vessel the other will be low also. Of course, the displacement coefficient rule was easier applied, and is, therefore, in more general use, but instead of the

augmented surface rule not being worthy of being used, it was certainly the more reliable of the two. Another point he should like to call attention to was with reference to the specimens of displacement coefficients given in the paper. The writer seemed to look upon the displacement coefficient as a constant. It was anything but constant, and the law that governed the variations in the coefficients were perfectly well understood, thanks principally to the model experiments of the late Mr. Froude. When Mr. Rankine published his book, the resistance of a ship at any speed was supposed to be in proportion to the augmented surface multiplied by the cube of the speed. That had been found by Mr. Froude's investigations not to be the case. The skin resistance of vessels does not vary exactly in proportion to the augmented surface; but it rather decreased for the same speed in proportion to the increase in the dimensions of the vessel. This was very well shown by comparing the coefficients $\frac{D^{\frac{2}{3}} \times S^2}{I.H.P.}$, say for a torpedo boat and an Atlantic liner. Take the torpedo boat as 100 ft. long and the Atlantic liner 500 ft., both for 20 knots speed, the coefficients in the torpedo boats would be 120, or thereabouts, and the other 280 or 300, and between these two extremes they would find coefficients of all values. Then, again, the way in which coefficients were modified by increasing the speed is shown very well in all progressive trial results. They would find there in any steamship that the coefficient for one speed, say 10 knots, would be much higher than that at 12 knots, and this again would be higher than that for 14 knots speed, and so on, the coefficients getting higher as the speed decreases and lower with every increase of speed, showing that the resistance to increased speed is greater than in proportion to the cube of the speed. He had known as much as 20 to 30 per cent. difference in the coefficients in these progressive trial runs. He did not think it right to allow these views of the writer to be passed over without remark, as they might lead some of their younger members astray. There was one other point perhaps he might mention. From his own observation, and what he had been told, he understood that in this district the makers of the engines almost invariably determined the horse-power necessary to drive the ships at any given speed. That is to say, a shipbuilder designs the ship, the engineer has no control over the design in any way, and very likely has not even seen it, but he says he will drive it at a certain speed with a power which he gives. No, no. He heard some gentleman say "No;" but he knew cases such as he mentioned that had come within his own observation, and he had been told by several engineers

who supplied a large number of engines to shipbuilders in the district that they simply get the principal dimensions, the coefficient of displacement, draught, and speed wanted, and that the power was then determined by the engineer. Of course there would be exceptions to this rule, but he understood that what he had stated was the general practice here. He hoped it was not because the shipbuilders were not able to calculate the power necessary to drive a ship at any given speed that this practice prevailed.

Mr. W. G. SPENCE wished to add some remarks to the discussion on Mr. Arnison's paper, and, perhaps, one of the reasons for his desiring to do so was, that in speaking at the discussion on Mr. Hall's paper he expressed a desire that the area of immersed Φ should be added to the list of particulars given by that gentleman, as this was the only item omitted which was necessary for the computation of the approximate wetted surface of each vessel by the method known as Kirk's analysis or equivalent block. From the remarks therefore at the beginning of Mr. Arnison's paper, it would appear that he had been to some extent an unconscious item in the development of the reasons for bringing forward this paper. Following upon this text, the writer seemed, as far as his (Mr. Spence's) light leads him, to enunciate that being already in possession of the actual displacement of a proposed vessel, he would obtain no further guidance in predicting a probable speed by being likewise informed of the ship's actual wetted surface. Well, this might or might not be the case, but before deciding it would be well to first consider on what elements the $D^{\frac{2}{3}}$ coefficient, for which the writer showed preference was based, for, as far as he (Mr. Spence) knew, all three expressions, viz., the midship section, $D^{\frac{2}{3}}$, and augmented surface, were founded on the assumption, that the greatest percentage of resistance to propulsion was due to skin friction, and that this varied as the square of the speed, and, consequently, any dimensions that would indicate the relative amounts of wetted surface in two vessels would be a means of approximating their relative resistance to motion. Taking first the midship section formula. *In exactly similar type ships* the midship sections vary as $d \times b$, and as under similar circumstances the immersed skin also varies as $d \times b$, the midship sections can be used as an index of the *relative* amounts of wetted surface, then this relation into the pressure of a head of water equivalent to the speed of the ship, will give a measure of the relative statical resistance to motion in two similar typed ships at varying speeds, provided the variations in speed set up no new sets of conditions around the vessels. Now, the equivalent head varies as the speed squared, and thus the relative pressures can be indicated by

using v^2, therefore, surface by v^2 by distance moved through will be an index of the amount of *work*, and may be expressed as $(\Phi \times v^2 \times v) = \Phi \times v^3$, and if this be divided by the horse-power developed, ought to give a constant quantity, hence, as the result, we have the expression

$$\frac{\Phi \times v^3}{\text{I.H.P.}} = c \quad \text{(A)}.$$

But the mere knowledge of the amount of immersed Φ, in the case of two vessels varying in the least in type, affords no clue whatever to the relation between their immersed skin surfaces, as it contains within itself no factor of the length or fineness of the vessel, and, if it is to be used, must be coupled with some modifying coefficient to adapt it to the difference in hull, and would then stand

$$\frac{(\Phi \times y) \times v^3}{\text{I.H.P.}} = c \quad \text{(B)}.$$

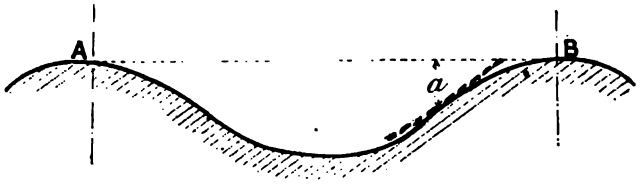
As the use of this coefficient y would in practice be out of the question, a quantity must be sought out which contains within itself some corrective factor, enabling it to give a nearer approach to the relation between the wetted surfaces. Now, the displacement $D = (l \times d \times b \times \text{coefficient})$, but l, d and b are each proportionate to $D^{\frac{1}{3}}$, therefore $D^{\frac{2}{3}}$ is proportionate to $b \times d \times$ a coefficient, that is midship section $\times$ a coefficient, so instead of using the expression (B) the same result can be got by substituting $D^{\frac{2}{3}}$ for $(\Phi \times y)$, and thus we have the formula

$$\frac{D^{\frac{2}{3}} \times v^3}{\text{I.H.P.}} = c.$$

which contains within itself a modifying factor y not contained in the mere Φ simply, and, therefore, without adducing any actual practical results, it might be pretty safely predicted, that the expression $D^{\frac{2}{3}}$ would give a nearer approach to the relative resistance of two vessels slightly varying in type. But the $D^{\frac{2}{3}}$ is only a very rough approximation to the relation of the wetted skins, and itself requires some modifying coefficient to adapt it to the two vessels, and, it would seem to him at least, that a more reasonable method of proceeding would be, not to *assume* that the surface varied approximately as the $D^{\frac{2}{3}}$ or anything else, but to commence by using the actual wetted surface itself as a basis of operations; if this cannot be obtained, then the next best thing would appear to be to seize upon any particulars by which a nearer approach to it could be got; and, with all due deference to the writer, he would suggest that a nearer approach to it could be got by the use of the equivalent block or Kirk's analysis (a method of which not even mention is made in this paper),

and if the surface thus got be still further modified by a coefficient obtained by comparing a number of block surfaces for varying ships with the actual surfaces, a quantity will be got which gives a much better guide to the amount of surface in a vessel than anything deducible from the $D^{\frac{2}{3}}$. Also, in the calculation of the approximate surface by Kirk's method, no particulars are required which are not, or should not, be in the hands of a builder in designing a vessel. The writer then proceeds to point out that in his experience the constants as got from the $D^{\frac{2}{3}}$ expression are of a less variable nature than those obtained by using Professor Rankine's augmented surface formula, in which Rankine discarded the assumption that the surface varied as the $D^{\frac{2}{3}}$, and based his deductions on the amount of actual wetted surface itself. Now, he thought, it would have much strengthened the position taken up by the writer if he had pointed out one single *reason* why the variation *should* be less. Rankine based his reasoning on the argument that in *well-lined* ships of a *length sufficient* for the speed at which they were to be driven, the frictional resistance of the water against the skin of the ship forms much the greater percentage of the total resistance to motion, and is composed of the resistance due to the formation of frictional eddies caused by the adhesion to the skin of the ship of the particles of the layer of water which glide over it. The velocity with which the particles whirl in these eddies bears some fixed proportion to that with which they glide over the ship's surface. The velocity of gliding of the particles of water over a portion of the ship's skin bears, therefore, a ratio to the speed of the ship, depending on her figure and on the position of the part of her skin in question. He considered that the resistance due to the formation of these eddies would have to be calculated from a velocity which would, in the mean, exceed that of the forward motion of the ship simply, and to allow for this, instead of using in his formula an increased forward velocity of ship, he did what amounted to the same thing, namely, increased the actual wetted surface by an amount, which he considered would compensate for neglecting the increase of speed of whirling; this additional surface, plus the true wetted surface, is usually termed the augmented surface, a term which is somewhat misleading, as what is really being dealt with is augmented velocity. He assumed the surface of the ship to form a trochoidal riband or rolling wave curve, and by integration found that the augmented surface of a trochoidal riband of given length and breadth $= L \times B \times (1 + 4 \text{ Sin.}^2 a + \text{Sin.}^4 a)$, the length being taken between the points A and B, and the angle a measured at the point of contrary flexure. (See sketch, page 49.)

In the case of a ship, he assumed the length of the riband as being that of the ship on the load water-line, the breadth as being that of the ship's



mean girth, and the angle as that of the entering angles; then $l \times my \times$ coefficient augmentation = augmented surface. Having determined this coefficient of augmentation the resistance to motion of the ship is composed of the following factors:—

1st. The actual wetted skin × coefficient of augmentation = augmented surface.

2nd. The height of the head of water equivalent to the forward motion of the ship, or $\frac{v^2}{64}$ or $\frac{(\text{speed in knots})^2}{22{\cdot}6}$.

3rd. The weight m of a unit volume water (64lbs. per cubic foot for sea water).

4th. A coefficient of friction c, depending on the state of smoothness of the ship's skin.

The total resistance R, may then be expressed as

$$R = c\, m\, \frac{v^2}{64} \text{ augmented surface.}$$

For the coefficient of frictions Rankine used that deduced by Weisbach from the flow of water in iron pipes, viz., $c = 0{\cdot}0036$. Now, say speed = 10 knots per hour = 17 feet per second, the equivalent head due to a velocity of 17 feet per second = 4·5 feet, and substituting this for $\frac{v^2}{64}$ the resistance R at 10 knots per hour =

$$R = 0{\cdot}0036 \times 64 \times 4{\cdot}5 \times \text{augmented surface.}$$

$$\therefore R = 1{\cdot}037 \text{ augmented surface.}$$

Or, in other words, Rankine estimated that, at a speed of 10 knots per hour, the eddy resistance of clean painted vessels practically = 1lb. per square foot of augmented surface, and for any other speed it would vary as the height of the equivalent column or v^2, thus for a velocity of v knots per hour

$$R = 1{\cdot}037 \times \frac{v^2}{10^2} \times \text{augmented surface.}$$

But the *work* done in any time depends on the distance through which

the resistance is overcome, and is therefore measured by resistance × distance; the work done, therefore, in a given time in overcoming eddy resistance at a speed of v knots per hour =

$$w = 1{\cdot}037 \times \frac{v^3}{10^3} \times v \times \text{augmented surface.}$$

$$w = 1{\cdot}037 \times \frac{v^3}{10^3} \times \text{augmented surface.}$$

Now an I.H.P. = 33,000 foot-pounds per minute,
I.H.P. = 550 „ „ „ second.
And 1 knot per hour = 1·688 feet per second.

$$\therefore \text{ 1 I.H.P.} = \frac{550}{1{\cdot}688} = 326 \text{ knot-pounds per hour.}$$

But Rankine argued that of the gross I.H.P. developed, only some 63 per cent. would be usefully employed in overcoming the resistance of the vessel; therefore, if v = knots per hour, the gross horse-power required of the engine

$$= \text{I.H.P.} = \frac{1{\cdot}037 \ \frac{v^3}{10^3} \times \text{augmented surface.}}{0{\cdot}63 \times 326.}$$

$$\therefore \text{ I.H.P.} = \frac{1{\cdot}037 \ v^3 \times \text{augmented surface.}}{20{,}000.}$$

$$\text{Practically I.H.P.} = \frac{v^3 \times \text{augmented surface.}}{20{,}000.}$$

From the foregoing sketch of the elements of the three expressions it would, he thought, be seen that instead of there being any difference of basis they were all three founded on the same thing; only, that Rankine's rule dealt with the actual amount of a quantity, namely, the wetted surface, a mere approximation to which is only attempted by the use of the term D^4, and it likewise also possesses within itself a corrective value to help it to meet cases of bluffness of lines [illegible] although, unfortunately, (as the writer has very well pointed [illegible] it possesses none for meeting cases of fulness of run aft. It also possesses a correction for wave-making due to relation of length of ship to [illegible] At the same time, it must not be forgotten that Rankine had to [illegible] while in the possession of very limited data, and that he [illegible] speculated that his ships must be of good lines; and, with all due [illegible] to Mr Yeamon's loss of confidence in it, it contains no element [illegible] which can be left neglected: it was the first [illegible] attempt at forming an expression by which the power of a [illegible] will be determined by *a priori* reasoning from first principles;

and, had he lived to finish his work and been in possession of the varying type ship progressive trial data now attainable, it is only fair to conjecture, he would have introduced into it further corrective values, which would have rendered it more elastic for difference of type and variation of speed; while possibly he would have been somewhat surprised to find it expected to fit in, in cases where it was certainly never intended to be used.

The VICE-PRESIDENT (Mr. Coote), being obliged to leave, expressed his pleasure in coming over to Sunderland, and said he was especially anxious that they should visit each other. He had thought that they did not come over from Newcastle in sufficient numbers, and perhaps they did not go as they might from Sunderland to the meetings in Newcastle. Their aim should be to make the "North-East Coast" a standing name for the united shipping interest of the whole district. They heard of a "Clyde-built ship," for instance, not but that it might be built at Paisley, Greenock, or Dumbarton, and so it should be with them—not Sunderland, Hartlepool, or Tyne, but one equally high standard, viz., the "North-East Coast." Mr. Taylor (Vice-President) had consented to take the chair.

Mr. W. A. F. CRAWFORD, resuming the discussion, said, he had little doubt that he also was one of the members who had induced the author to compile the paper he had just read, and he had to thank him for the opportunity of discussing some of the points raised; but he was not aware that in the discussion on Mr. Hall's paper he threw any doubt on the advisability of using the equation, $C = \frac{D_{\frac{2}{3}} \times v^3}{I.H.P.}$, for it was on record that he stated, "that as the equation was only true within very narrow limits, it was both requisite and necessary"—considering the importance of the deductions—"that the comparisons should be made under approximately similar conditions," or that the inference regarding the importance attached to formulæ involving the "mid section" was altogether warranted, as this last information was expressly desired for the purpose of comparing the ships on the "basis of their equivalent blocks." In an equation for the resistance to a ship's motion, the displacement alone, or any function of it, could not be correctly used unless we assumed the displacement to vary as the cube of a lineal dimension governing it, and thus circumstantially admit that the function D^3 was only applicable to similar ships; and while he admitted the function was a commercially valuable one, he thought that it owed its success mainly to the fact that it varied approximately as the wetted

surface, as might be shown by measurement; but good practical proof had been furnished by Mr. Hall in his reply to the remarks on his paper,* where he states that the difference in the "constants" derived from $C = \frac{D^{\frac{2}{3}} \times v^3}{I.H.P.}$ —*i.e.*, 232 and 260·5—for the same ship under practically similar conditions, save (as was afterwards pointed out) the condition of the wetted surface "was simply due to the fact that, when the ship made the good performance she had been newly docked and cleaned, the remaining part of the work was done without having been previously in the dock," showing clearly that the skin friction was mainly responsible for the remarkable difference; and it would be interesting for owners to note that had the wetted surface been in the same condition the first voyage as it was the second, she would have gone the same speed—10·05 knots—on the round voyage with about 160 tons less coal. In regard to the statement that "theory sometimes proved to be misleading," he wished to point out—that the younger members, at any rate, should not be misled—that a theory should be viewed as speculative reasoning set forth to be proved, and, as soon as it had satisfied each and every condition that was claimed, it might become a law, and rules based on the doctrines set forth could be safely used by those understanding them; failing to satisfy the conditions claimed, it should pass into oblivion, or, if it had any residual merit, into the region of speculative amenities for the benefit of enquiring students. But that man deserved to be misled who would take advantage of another's reasoning without troubling himself to discover whether he was complying with the conditions imposed upon him. And, further, in dealing with this paragraph he would like to draw attention to the fact as showing how far Rankine with his theory—or, more correctly, with his great inductive capacity—was ahead of the professional knowledge of his day; that when in 1857 (or five years prior to the author's reference) Mr. James Napier first asked him to deduce a general formulæ for the resistance of ships, from data in his (Mr. Napier's) possession, Rankine's "very first words pointed out to him what a large proportion of the resistance to a vessel's motion is due to skin friction, and how ill-considered was the then growing demand for long narrow ships." Again, he thought it would be well to remember that when Rankine published his formulæ the speed and configuration of steamers were very different to what they are now, that while Rankine—as Mr. Napier records—solved the problems at that and

* See *Transactions*, Vol. III., page 271.

subsequent periods, with the required exactness, it was scarcely fair when the conditions were so much altered to expect the same degree of exactness with the same general formulæ; and, he thought, if the author had remembered that a propeller loses an indefinite percentage of its efficiency when not immersed, he would not have looked for an exact prediction, but would have amended his "constant" to suit the altered conditions, and thus saved his confidence in the "augmented surface rule," and the severe shock it had sustained. As he had already said, the equation $C = \frac{D^{\frac{2}{3}} \times v^3}{I.H.P.}$ had a certain limited value, but as far as any expression in it was concerned, the speed was independent of the form and condition of the hull, and it should, therefore, be used only as a first approximation, but if greater accuracy was required, formulæ involving the form and condition of the hull, with constants from our own experience, must be used.

Mr. M. SANDISON said, it was about 1865 that the late Mr. Denny advocated very strongly the desirability of the progressive speed trials to which Mr. Adamson had alluded. He thought curves of constants got from such trials were among the most valuable pieces of information a shipbuilder could possess. These curves were very interesting, and, he thought, it was worthy of note in laying down curves of that sort, that in a great many cases they would find for every speed, except the speed of maximum efficiency, there was another speed for which the same constant held, depending of course, on the nature of the curve. Of the formulæ recapitulated the augmented surface is, he thought, undoubtedly the one most preferably to be adopted in analysing the performance of steamships. He might say that to save calculation, he should, with their permission, be glad to add as an addendum to the paper, a table of coefficients of augmentation calculated for all the angles which usually obtained in practice, and which, as far as he was aware, had not been published before.*

Mr. THOMAS MILLAR said, Mr. Arnison had opened up a subject which led to endless discussion, for no question in naval architecture had received more attention from eminent men in years past than the theory of the propulsion of steamships. Although early theories of resistance had been discarded in favour of the "stream line" theory, it was to be regretted that no really definite conclusions had been arrived at regarding this most important question. Professor Rankine had done much

* This Table will be found on page 64.

towards the practical application of this theory, and the soundness of his views had been, in a great measure, confirmed by the late Mr. Froude. Until something conclusive had been arrived at, they would require to continue using the present well-known formulæ, of which one of the previous speakers had given a very full description. The writer seems to deprecate the importance attached to the "midship area" and "wetted surface;" but, as there was no ready means of arriving at the "approximate wetted surface" without using the "midship area," there could be no doubt that the value of Mr. Hall's paper, for the purpose of comparison, was greatly enhanced by the addition of the "midship area" to the tables. Mr. Arnison goes on to say that there is "a tendency to discount practical in favour of theoretical results." Now he (Mr. Millar) did not think that such was the case, as he generally found that results obtained in practice were accepted in preference to any experimental data which could be obtained, although reliable experimental data was only too gladly received. The writer says, "he has yet to learn of any better method of gauging results than by the coefficient $D^{\frac{1}{3}}$, or, in special cases, Mr. Mansel's modified coefficient," which, by the way, he does not give. Mr. Mansel's coefficient is based upon the variation of resistance at different speeds, and can be applied to either of the Admiralty coefficients. A full and interesting explanation of this modified coefficient was given in *The Engineer*, of 21st May, 1886. Mr. Mansel certainly obtained some wonderful results from the use of his coefficient; but it would be found, upon examination, that what was really a constant at all speeds for one vessel, would be found to vary two or three times in the speeds of another vessel. Of course, this is not so bad as the Admiralty coefficients, which vary at different speeds and different displacements. There could be no doubt that by a judicious use of the "wetted surface" or "augmented surface" a more correct approximation of the power necessary to drive a vessel could be made than by the use of either of the Admiralty coefficients. He thought that the great factor in using any of the coefficients was experience; and designers, who knew anything of the subject at all, were little likely to use the same coefficient indiscriminately for different types of vessels, but would take proportions, etc., into consideration, and estimate accordingly. Of course, he supposed that the builder had full power—as he should have—to fix the dimensions of any vessel for which he might be asked to tender, and did not simply alter the dimensions which might be proposed to suit "modifications of scantlings," as inferred by Mr. Arnison. He did not think any builder ought to be responsible for the performance of any vessel the dimensions

of which were not fixed by the builder. While agreeing with Mr. Arnison that "data derived from actual practice should be made public," he did not think that builders were very anxious to disclose results which were often obtained at considerable expense, and which, if published, might prove quite as misleading, as Mr. Arnison said theory sometimes had proved to be. Regarding the objection raised by the writer to the use of the "augmented surface," on the ground "that it requires quantities which can only be obtained when the design has been completed." Now that the entrance and run of steamers were practically of the same length, Kirk's analyses formed a ready method of arriving at the approximate "wetted surface" or "augmented surface," and that before the design was even begun, consequently, the objection to its use on that ground does not hold good. The factors necessary for the manipulation of Kirk's block are—moulded dimensions, length, breadth, and draught, displacement, and midship area. From this the "block surface" could easily be obtained, and only required to be multiplied by a coefficient to arrive at the "wetted surface" due to the hull. The result, multiplied by the coefficient of augmentation, gave the augmented surface. Of course, due allowance had to be made for appendages. The coefficient of augmentation was got from the mean angle of entrance and run. The augmented surface coefficient of 20,000, given by Professor Rankine, was subject to considerable variation, and, in instances which he knew of, ranged from about 10,000 to 30,000. This might seem rather a wide range, but when they considered that the variation was in the same ratio as the Admiralty coefficients, he thought, that by using the augmented surface coefficient the liability to error was lessened, care being taken that results, obtained from vessels of very much the same proportions, be used for the purpose of comparison. The sliding scale designed by Mr. Mansel was simply a logarithm scale, and could be extended to any displacement, speed, or horse-power, so that Mr. Arnison, in working out his results by logarithms, was just doing what the scale could be made to perform. The speed scale in use in their office was a modification of the scale mentioned, and contained the augmented surface coefficient as well as the Admiralty coefficients. It had been extended so as to embrace any displacement, speed, etc., which was likely to be met with, for the next few years at any rate; and he did not think, with all due respect, that Mr. Arnison could work out results by figures quicker than the scale could be used. In Tables I. and II., page 42, the most important items had not been given, viz., moulded dimensions, length, breadth, and draught, so that for purposes of comparison the tables were not of much

use. If Mr. Arnison would kindly introduce these dimensions, it would enable the members to make some practical use of the results given. Again, in Table I., the paddle steamer "F" should not have been introduced, as the results obtained for paddle steamers were never so good as those obtained from screw steamers. The other figures given in the tables compared fairly with one another; and, given the dimensions, could with judgment be used practically with satisfactory results.

Mr. J. JOHNSON said, the reason why the midship area speed coefficient gives a different result to the displacement speed coefficient is simply this, that the proportion between the midship area and the $\frac{2}{3}$ power of the displacement is seldom the same in every vessel. If Mr. Arnison had taken account of the *corresponding speeds* he would, to some extent, have found an explanation of the varying results obtained from the Admiralty speed formulæ. It was just by means of experiments with models that the late Mr. Froude discovered the law of *corresponding speeds*. Before his time experimentalists very often came to wrong conclusions, because even if they anticipated the existence of such a law they did at least not know the nature of it. It is only in vessels of the same size, built on similar lines, similarly propelled, and having the immersed surfaces in the same conditions that we can at all expect to find the speed coefficients equal, when driven at the same speeds. But if the vessels, although being built on similar lines, are of different size, then the speed coefficients will be equal, not at the same speeds, but at the *corresponding speeds*. On that basis a most ingenious system of recording progressive speed trials was introduced some years ago on the Clyde by Mr. J. Inglis, jun., which system has since been slightly modified by Mr. Biles, and he (Mr. Johnson) knew of no more correct or more convenient method in existence. Supposing that some of the vessels, of which examples were given in the tables, page 42, were built on similar lines. For instance, the displacement speed coefficients of steamers G and H are very nearly alike, and the reason is not very far to seek, as the speeds at which these coefficients are taken happen just to be practically the corresponding speeds. The corresponding speed of steamer H to 14·05 knots of steamer G is $= 14{\cdot}05 \sqrt[6]{\frac{7341}{8610}}$ $= 13{\cdot}68$ knots, against 13·55 knots in the table. In the same manner, if we want to compare the performance of steamers I and J with that of G, we must take the speed coefficients of I at 13·64 knots, and of J at 13·52 knots instead of at 12·05 knots. And of the examples given in Table I., the speed of steamer E corresponding to 11·85 knots of A is

12·44 knots instead of 13·4. As it was getting late he would only make a few remarks further, referring to some of the statements on page 39. Mr. Arnison evidently invited a debate on the vexed question of hollow *versus* entirely convex lines in the bow, and also the proportion between the lengths of entrance and run. He would not believe that Mr. Arnison entertained a notion that there is a certain paragon form which will secure the minimum resistance under all conditions. Here, like in every other question pertaining to ships' resistance, we have to fall back upon model experiments for information. These experiments have most clearly pointed out that, say for a ship of a given size, the shape of the immersed hull should be governed chiefly by the intended speed and mode of propulsion. The lines adopted in the modern high speed man-of-war ships, the shape of which have all been obtained from exhaustive model experiments, demonstrates this most clearly. By means of experiments with models, which had very hollow lines at the bow, it was found that this hollow was an advantage at some speeds and a disadvantage at others. If we, therefore, find that the adoption of straight lines has proved a success in one vessel at a certain speed, we must not draw the conclusion that all ships should have the same shape. He could not agree with Mr. Arnison that fine fore-body lines necessarily decreases a vessels sea-going qualities. Fine lines in the fore-body are of course always, in a well-designed vessel, accompanied by proportional fineness of the after-body, and he knew of no better sea-going vessel than the modern steam yacht, built for all-round cruising; vessels built on finer lines could hardly be found. The distribution of the cargo and other weights had also got something to do with a vessels sea-going qualities. He should also like to ask Mr. Arnison why he would place the midship section further aft in a paddle steamer than in a screw steamer. Every one who has experience in designing paddle steamers knows how difficult it is, especially if there is no recourse to model experiments, to place the paddle wheels in a position where they will exert the most energy. One might be unfortunate enough to place the wheels so that they work in a hollow of the transverse waves, which accompany every vessel, and thus get an undesirable amount of slip. The position of the wheels and other machinery affects the longitudinal position of the vessel's centre of gravity, and, as the centre of buoyancy must be in the same transverse plane as the centre of gravity, in order to secure a graceful distribution of the displacement, these things must also be taken into account when fixing the relative lengths of entrance and run.

Mr. ARNISON thanked the members for their kind attention, but

stated that there appeared to have been some misconception as to the scope of his paper. He reminded them that it was not his purpose "to review the entire subject of steamship speed calculations," far less was it his intention to consider the intricate problems of ship resistance. In the limits of a brief paper it would have been impossible. No apology is therefore necessary for alleged omissions. He would, however, suggest that some of the members—more especially those who had taken part in the discussion—should, during the present session, give some account of *their* experience with Kirk's analyses, and of other speed calculations. Mr. Adamson had stated :—"In one part of the paper he (Mr. Arnison) said he had had his confidence destroyed in the coefficient for calculating speed in which the augmented surface forms one of the terms." Now, the passage referred to will be found on page 41, and it does not state that "confidence" in the *coefficient* was destroyed, but in the "*augmented surface*" *rule*. Whatever may have been the practice of those who have used the "augmented surface" rule, it is clear, from page 84 of *Shipbuilding: Theoretical and Practical*, edited by the late Professor W. J. Macquorn Rankine, C.E., LL.D., that the coefficient of propulsion used in the rule of "augmented surface" was to a large extent a constant, as will be seen from the following quotation :—

"In clean iron ships, with no evident fault in shape or dimensions, or in the propeller and engine, it has been found on an average to be *somewhat above* 20,000; and the value 20,000 *may be taken as a probable and safe estimate of the coefficient of propulsion in any proposed vessel designed on good principles.* In every instance in which that coefficient is materially less than 20,000, the shortcoming can be accounted for by some fault, such as those described in Article 158. For example, in the vessels designated in that article as X and Y, the coefficient of propulsion was about 16,000, the deficiency being probably caused by shortness of the after-body; and that of the vessel V, whose after-body was of the proper length, but the fore-body rather too short, was about 19,000."

Now the vessels D and E had "no evident fault in shape or dimensions, or in the propeller and engine," nor was there a deficiency in the length of the fore-body or the after-body, and yet the actual coefficient of propulsion in the case of E, with the propeller well immersed, was under 18,000. It was therefore only reasonable to conclude that, even for vessels "designed on good principles," the "value 20,000" was misleading. As it then (*i.e.*, upwards of ten years ago) became necessary to rely entirely upon past experience in fixing the power of a proposed vessel's engines, the coefficient—

$$= \frac{D^{\frac{2}{3}} V^3}{\text{I.H.P.}}$$

was adopted, which, it is admitted by Mr. Adamson, is "easier applied." That gentleman, however, also affirmed that "the augmented surface rule" is "certainly the more reliable of the two," but gave no reason for this opinion. It must be however very clear, that the "augmented surface rule," strictly defined, is unreliable.

Mr. Adamson stated that "the writer of the paper seemed to look upon the displacement coefficient as a constant," to this he must give a distinct negative. The various coefficients of speed efficiency given in Tables I. and II., and for one vessel in the closing paragraph of the paper, all point in the opposite direction; and how Mr. Adamson formed the opinion he (Mr. Arnison) was at a loss to know. To make this matter very clear, it may be stated that the writer of the paper has on various occasions taken out the speed coefficient of efficiency of displacement for various speeds of the same vessel. It may be of interest to refer to one instance, that of H.M.S. "Howe," of which the results are as follows :—

No. of Trial.	Speed in Knots.	$\frac{D^{\frac{2}{3}} \times V^3}{I.H.P.}$
1	8·938	281·2
2	10·250	285·4
3	13·386	265·0
4	15·873	220·1
5	16·923	189·3

Now, if the coefficient had been constant, say 281·2 in all but one instance at the higher speeds, there would have been considerably less horse-power required, as will be seen in the following table :—

No. of Trial.	I.H.P. calculated to vary as V^3.	Actual I.H.P.
2	1,734	1,709
3	3,861	4,099
4	6,442	8,230
5	7,806	11,613

Progressive speed trials had been mentioned by Mr. Adamson, and it had been the writer's intention to give the detailed results of the progressive trial trips of the steamers D and E, but these results would not have added to the value of the paper, nor forcibly demonstrated the fact mentioned in the third paragraph of the paper, that "when steamers are driven at a higher speed than that they are adapted for by their dimensions and form, the resistance is in excess of that corresponding to the cube root of the square of the displacement, and the power increases *at a higher rate than the cube of the speed*," a paragraph apparently overlooked by Mr. Adamson.

Regarding that gentleman's closing remarks, the writer of the paper would suggest that the instances referred to, where the engineers and not the shipbuilders fixed the power of the engines, were not recent.

Mr. W. G. Spence's contribution to the discussion, in reasoning out of the advantage of using the cube root of the square of the displacement in place of the area of immersed midship section, although not considered necessary by the writer of the paper, only emphasised his (the writer's) views. Indeed, no serious exception need be taken to anything Mr. Spence advanced, until he stated, "The writer then proceeds to point out that in his experience the constants as got from the $D^{\frac{2}{3}}$ expression are of a less variable nature than those obtained by using Professor Rankine's augmented surface formula." If Mr. Spence will re-read his (Mr. Arnison's) paper he will fail to find anything to justify this alleged summarisation. It was therefore quite unnecessary to notice Mr. Spence's criticism, that "he thought it would have much strengthened the position taken up by the writer if he had pointed out one single *reason* why the variation *should* be less," as in no part of the paper is it shown that the variations differ. Had this been a point in question, Tables I. and II. would have included the "values" of the respective vessels, as derivable from Rankine's formula. As Mr. Spence went on to say, that Professor Rankine "based his reasoning on the argument that in *well-lined* ships of a *length sufficient*," etc., it may be here *again* stated that the screw steamers D and E were "*well designed and fine lined*," and of "length sufficient" not only for the speed they were driven at, but for a higher speed than 15 knots.

No doubt Professor Rankine deserved credit for being foremost in systematically attempting to form "an expression by which the power of a vessel could be determined by *a priori* reasoning from first principles," although it is to be regretted that that expression did not take into account the relative fineness or fulness of the after-body. It must, however, be remembered that there were earlier workers in this department. Referring to the resistance owing to "skin friction," and "increase of the pressure at the bow and diminution of the pressure at the stern," Professor Rankine himself says, on page 81 of *Shipbuilding: Theoretical and Practical*:—"The existence of this kind of resistance has been recognised from an early period. Beaufoy made experiments on models to determine its amount; Mr. Hawksley and Mr. Phipps have included it in a formula for the resistance of ships; and Mr. Bourne pointed out that it must depend mainly on the ship's immersed girth." It may be as well to complete the paragraph this is extracted from. "But the earlier researches, both experimental and theoretical, throw little light on the subject, and fail to give a trustworthy value of the coefficient of friction, because in them it was assumed that the frictional resistance was proportional to the *actual immersed surface* of the vessel, and the variations

of the speed of the gliding of the water over different parts of that surface were neglected."

In reply to Mr. Crawford, the writer of the paper stated that the inferences he had drawn from the discussion on Mr. J. P. Hall's paper on "Compound *v.* Triple Expansion Engines from a Shipowner's point of view," whether they were correct or incorrect, had finally caused him (Mr. Arnison) to put into their present shape the views expressed in the "Notes on Steamship Speed Calculations." As regards a "propeller" losing "an indefinite percentage of its efficiency when not immersed," he (Mr. Arnison) would point out that in the sister vessels D and E it was only with regard to the former that it is stated in the paper "the propeller was not entirely immersed." As to coefficients of speed efficiency varying according to circumstances, abundant evidence of that is shown in the last paragraph of the paper, where the same vessel is shown to have given on carefully ascertained voyage results coefficients of speed efficiency of displacement as low as 209 and as high as 255·2.

The table of coefficients of augmentation appended by Mr. M. Sandison may be of use to those using the "augmented surface" rule in ordinary cases, but there are extreme variations in such coefficients. In one instance, for a vessel which attained a speed of 10 knots, the coefficient of augmentation was as high as 2·504.*† In this instance the draught of water and length of vessel were necessarily limited. In using Mr. Sandison's table care will have to be exercised that the "mean angle of obliquity" is carefully ascertained, an operation necessitating calculation wherever there is much variation in the form of the vessel in the forward section.

It was unnecessary to traverse the whole of the ground covered by Mr. Millar, but the writer of the paper cordially endorsed the remark "that the *great* factor in using any of the coefficients was experience, and designers who knew anything of the subject at all were little likely to use the same constant" (preferably coefficient) "for different types of vessels, but would take proportions, etc., into consideration." He must, however, differ from Mr. Millar's arguments in favour of the retention of "data" by private firms—as if that policy was universally carried out there would be practically nothing for such institutions as the North-East Coast Institution of Engineers and Shipbuilders to discuss. As to whether "any builder ought to be responsible for the performance of any

* Rankine states, "This rule is not applicable to vessels which are so bluff at the bow and stern as to push before them or drag behind them a mass of water full of whirling eddies; for in such vessels the assumption that the water agitated by friction is a very thin layer, is not fulfilled."—B. G. N.

† The vessel alluded to is a ferry steamer plying on the River Mersey.—Ed.

vessel the dimensions of which were not fixed by the builder," Mr. Arnison thought there was room for two opinions. Being partially indebted to other gentlemen for the particulars of the vessels referred to in his paper, he regretted he could not see his way to comply with Mr. Millar's suggestion, to give the moulded dimensions, etc.

As regards Mr. Mansell's modified coefficient, it was not given in the paper, as the writer strictly limited its scope, and more than a passing notice of it was thus unnecessary. It may, however, be pointed out that not only in *The Engineer* of May 21st, 1886, but also in subsequent issues of that paper, viz., June 18th, September 3rd, and October 1st, 1886, examples of it are given by Mr. Mansell. Mr. Millar had stated that the paddle steamer F should not have been included in Table I., but in reply Mr. Arnison stated it was only given to show the variation of midship section area coefficients and displacement coefficients of speed efficiency.

Referring to Mr. Johnson's remarks, the writer of the paper readily agreed if he "had taken account of the *corresponding speeds* he would, to some extent, have found an explanation of the varying results obtained from the Admiralty speed formula," but such an enquiry was beyond the scope of the paper. Neither was it his intention to provoke a discussion on "hollow *versus* entirely convex lines in the bow." Attention was only called to the fact that early steamers *had* "excessively fine fore-body lines." In no part of the paper did he affirm that "fine fore-body lines necessarily decrease a vessel's sea-going qualities," but with finer lines forward than aft, as in the "Great Britain" and many other *early* steamers, on account of plunging their heads into the seas, *they were*, "in nautical phraseology, very 'wet.'"

As regards placing "the midship section further aft in a paddle steamer than in a screw steamer," the writer of the paper laid down no absolute rule on the point. What he did say was—"It will be here noticed that the length of the 'run' is only two-thirds that of the 'entrance'; and the writer takes the opportunity of expressing the opinion that such proportions *may* be suitable for paddle steamers." The reason in the writer's mind for the possible advantage of having finer lines in the fore-body than in the after-body of a paddle steamer was a probable tendency would be to obtain more efficient work out of the paddle wheels.

In conclusion, Mr. Arnison again thanked the members present for the kind and courteous manner in which they had received his paper, and more especially those gentlemen who had taken part in the discussion.

A vote of thanks was accorded by acclamation to Mr. Arnison for his interesting paper.

The following communication has been received from Mr. W. Hök:—

"Mr. Arnison commenced by saying that a volume might easily be compiled about speed and power matters. He is quite right, if that volume is to contain a review of various formulæ for calculating powers and speeds, formulæ that have been by our foremost naval architects condemned and stamped as of little value years ago. It is a pity that these well-known Admiralty displacement and mid area constants have not by this time been buried in oblivion by the entire body of naval architects. As to Rankine's formula, in its present form it is also of little value, but has the advantage of being partly sound in principle, and will perhaps some day appear in another form and be of great value. To frame a formula with our present knowledge of resistance of ships is impossible. Those who know the limit for expressing phenomena in nature by means of algebra, and those who have an idea of the true resistance of a ship, not the resistance obtained by experimenting on the measured mile, which operation is so apt to be erroneous by carelessness, by wind, by tide, by the propeller being partly immersed, and by various other causes, but the resistance obtained from valuable and carefully conducted model experiments not liable in so great an extent to errors of great magnitude, those know with certainty that at the present time there is no possibility of expressing the law of resistance in a formula; and consequently also know that to estimate speed and power by means of any existing formulæ, whether they originate from Rankine, from the Admiralty, from Mansel, or from anyone else, is dangerous; and inasmuch as it leads to wrong conclusions, is followed by inevitable failures, as regards speeds of ships, and consequently by non-fulfilled contracts and pecuniary loss to the builder.

Mr. Arnison's reason for writing his paper is embodied in the following sentence: 'There is a tendency to discount results obtained from actual practice in favour of those obtained experimentally.' As far as I know, there is no such tendency. There are only the Admiralty and the shipbuilding firm of Messrs. William Denny & Brothers, that avail themselves of model experiments, and neither of those discount results obtained from actual practice in favour of those obtained experimentally. Those who make experiments with models have the advantage over us, that they know better than we do the great influence wind and tide have on speed trials; they know when a progressive trial has been successful; they know when the data obtained from a progressive trial can with safety be used for estimating speed for other steamers. He further adds that 'theory has sometimes proved to be misleading.' In connection with this it may be useful to point out that any

theory relating to resistance of ships will ever be misleading and erroneous, if it is founded on the assumption that the resistance varies as the square of the speed, or what amounts to the same, if the power varies as the cube of the speed, or even if the resistance curve is a logarithmic line as propounded by Mr. Mansel. Regarding the relative length of entrance and run of a ship, paddle and screw steamers can hardly be viewed together; but if it be a fact that in a screw steamer the loss from augmented resistance is generally less than the gain by the wake, as has recently been discovered by model experiments, then the natural inference is this, that a long run is of more importance in a paddle steamer than in a screw steamer, because in the former there is no gain by the wake.

Mr. Arnison says further, that Rankine's augmented surface rule entirely disregards the character of the run. It does not, if the mean angle of entrance and run is used instead of the angle of entrance only.

From a mathematical point of view it is wrong to compute the mean of the sines as is generally done. The sines ought to be multiplied by their respective Simpson's multipliers, because it is not the mean of the angles of the particular water-lines chosen for computing the mean angle that is required, it is the angle that would be obtained if the number of water-lines were infinite."

TABLE OF COEFFICIENTS OF AUGMENTATION GIVEN BY MR. SANDISON (See p. 53).

Angle.	Coefficient.	Angle.	Coefficient.	Angle.	Coefficient.
° ′		° ′		° ′	
4 0	1·0194	9 30	1·1097	15 0	1·2724
4 30	1·0246	10 0	1·1215	15 30	1·2907
5 0	1·0304	10 30	1·1339	16 0	1·3096
5 30	1·0368	11 0	1·1469	16 30	1·3291
6 0	1·0438	11 30	1·1606	17 0	1·3492
6 30	1·0514	12 0	1·1747	17 30	1·3698
7 0	1·0596	12 30	1·1895	18 0	1·3910
7 30	1·0684	13 0	1·2049	18 30	1·4128
8 0	1·0778	13 30	1·2209	19 0	1·4352
8 30	1·0878	14 0	1·2375	19 30	1·4580
9 0	1·0984	14 30	1·2547	20 0	1·4815

THE INFLUENCE OF COAL CONSUMPTION ON THE COMMERCIAL EFFICIENCY AND THE DESIGN OF CARGO STEAMERS.

By ROBERT THOMPSON, Member of the Council.

[Read before the Institution, November 16th, 1887.]

The continual improvements made in naval architecture and marine engineering have, year by year, altered the conditions upon which depends the commercial efficiency of steamships.

In building new steamers, shipowners pay considerably more attention now than formerly to improvements in the vessel's proportions, machinery, and outfit, in order to secure the highest possible economy, and the requirements of the trade for which the vessel is being built.

But complete success is never possible unless shipbuilders, engineers, and owners go hand in hand, endeavouring to consider the all-important question of economy from every possible point of view, and apply the knowledge that science and experience has taught them; and thus ensure the adoption of the most suitable size and form of ships to fulfil any required purpose.

In dealing with this question of efficiency and design, we at once enter into a subject of the utmost importance to the mercantile marine of this country, as there is scarcely a more difficult or more important problem for the naval architect to solve, than the fixing of suitable dimensions and proportions of the modern cargo steamer. In the first place, progressive speed trials, carefully conducted and recorded on scientific principles, and if possible, supplemented by model experiments, are absolutely requisite.

For the last three years all vessels built by the writer's firm, as far as circumstances have permitted, have been tried progressively on the measured mile, and from the results of these trials most valuable data have been obtained for guidance, when advising shipowners in the designing of their new vessels.

Some highly interesting and most ingenious investigations with regard to the economical working of cargo steamers were made a few years ago by Mr. J. Hamilton, of Glasgow, and described by him in a paper read before the Institution of Naval Architects, in 1883. In this paper he pointed out the gain in profit which would follow if cargo steamers, instead of being driven at the highest speeds, were run at slower speeds, depending upon the length of voyage; or in other words, for each vessel and each trade there is a certain speed which is most profitable.

The writer's firm, holding the same opinions as Mr. Hamilton, that the tendency of building cargo steamers on excessively full lines is a mistake, has adopted moderately full lines as being the most suitable for all general cargo purposes.

On the principles laid down by Mr. Hamilton, together with the assistance of data kindly given by some shipowning friends, the writer has been able to make the following investigations; and hopes the examples and results submitted for the criticism of the members of this Institution will prove interesting, especially since the conditions of freights, as well as expenditure, have undergone considerable changes in the last few years.

The introduction of the triple expansion engine is perhaps, next to the reduction of freights, the most material change, thus lowering the coal consumption from 2 lbs. to $1\frac{1}{2}$ lbs., or even less, per indicated horse-power per hour.

The economy is made up of so many elements, depending upon and comprising each other, that it is impossible to grasp the subject and form a decisive opinion unless the results of the investigations are accompanied by graphic illustrations.

As an example of the calculations made in connection with this paper, in the table facing this page, is shown in detail the carrying capacity, coal consumption, freight, expenditure, and profit for three steamers, all of which are supposed to be adapted for carrying cargo only, for different lengths of voyage.

In the same manner the profit per day has been calculated for the different lengths of voyage, at speeds varying from 8 to 12 knots, and the results shown in the diagrams on Plate II.

The principal dimensions of the three vessels are all similar, only the degree of fullness varying.

	Ft.	In.
Length on load-line	281	8
Breadth extreme...	36	6
Depth moulded amidships...	26	6
Mean draught from top of keel	21	4

Types	Steamer C. Speed = 10·45 Knots.					
Length of voyage in na	500	1,000	2,000	4,000	8,000	12,000
Steaming time ...	2·0	4·0	8·0	15·9	31·9	47·8
Loading time ...	6·3	6·3	6·3	6·3	6·3	6·3
Discharging time	10·3	10·1	9·9	9·3	8·1	7·0
Total time ...	18·6	20·4	24·2	31·5	46·3	61·1
D.W., including bunker	3,131	3,131	3,131	3,131	3,131	3,131
Coal on voyage ...	36·1	72·1	144·2	286·7	575·2	861·8
Reserve coal ...	7·2	14·4	28·8	57·3	115·0	172·4
Total coal	43·3	86·5	173·0	344·0	690·2	1,034·2
D.W., less bunkers	3,088	3,044	2,958	2,787	2,441	2,097
Freight	772	1,065	1,479	2,787	3,661	4,194
Coal	15·15	30·27	60·55	120·40	241·57	361·97
Oil, waste, &c. ...	3·33	6·66	13·32	26·49	53·15	79·63
Lights, dues, and pilota	68·25	68·25	102·38	136·50	136·50	136·50
Brokers' commission	54·04	74·55	103·53	195·09	256·27	293·58
Stevedoring ...	154·40	152·20	147·90	139·35	122·05	104·85
Wages and provisions	131·32	144·73	170·85	224·60	330·12	435·64
Repairs	13·95	15·30	18·15	23·63	34·73	45·83
Deck stores and sundrie	18·60	20·40	24·20	31·50	46·30	61·10
Insurance	126·85	139·13	165·04	214·83	315·77	416·70
Depreciation ...	63·42	69·57	82·52	107·42	157·89	208·35
Total expenditure	649·31	721·06	888·44	1,219·81	1,694·35	2,144·15
Profit for voyage ...	123	344	591	1,567	1,967	2,050
Profit per day ...	6·61	16·86	24·42	49·75	42·48	33·55

To face page 68.

	Prismatic coefficient of Displacement.	Displacement, in Tons.
Steamer A	·659	3920
„ B	·763	4535
„ C	·802	4766

The machinery of each vessel is similar, developing the same maximum indicated horse-power at sea, viz., 1120; and the maximum speeds at sea corresponding to this horse-power are, for A, 11·33; B, 10·72, and C, 10·45 knots per hour. Curves of indicated horse-power are shown on Plate I. The curve for steamer C is the actual result obtained from the progressive trial, and the curves for A and B have been reduced, by means of Froude's laws, from ships somewhat larger in actual size but similar in proportions and fineness. They have all been tried progressively at the load-line draft.

Of course the writer takes it that no shipowner would think of building a vessel as fine as A for carrying cargo only; but the calculations for this steamer only serve to complete the diagrams, and are not of vital importance, as far as the results of the fuller ships are concerned.

In deducing information from progressive speed trials the results of similar types, when compared, especially if the engines are by different makers, are often conflicting on account of the varying efficiency of the propeller and machinery, and in no case does this apply more than to very full cargo steamers.

The steamer C represents the best result of the performance of any full cargo steamer we have had confirmed in practice. For that reason the economical efficiency based upon the trials of steamer C shows a tendency of favouring the full types in comparison with finer ones, giving results *above* the average performance of such steamers. The writer's intention was to have given results of similar calculations derived from the average performance of a number of full cargo steamers, but unfortunately there has not been sufficient time at his disposal to give these fuller particulars.

Referring now to Plate II., we have there laid down to scale the profit per day for varying speeds and lengths of voyage. There is practically no difference in the first cost of the three types A, B, and C, so long as the machinery is the same, therefore these curves of profit per day will also represent very nearly the commercial efficiency.

The weight of machinery up to the highest speeds with 1·120 indicated horse-power has been assumed to be the same; but at 11 and 12 knots the weight has been allowed for in proportion to the required indicated horse-power.

Up to 2,000 or 3,000 nautical miles the freight is following an uniform ratio, but above 3,000 miles the actual freight increases at quite a different ratio; hence the jump in the curves. If the freights had an uniform ratio throughout for all voyages, the curves would arrange themselves for the steamer C, as the dotted lines in Diagram 3, Plate II.

With regard to the most economical speed, it will here be noticed that for steamer A (Diagram 1) the speeds from which we would expect the largest amount of profit are, for voyages under, say 7,000 miles, 11 knots, and above 7,000 miles 10 knots. For steamer B (Diagram 2) the most profitable speed up to 10,000 miles is 10 knots, and above that 9 knots. Similarly for steamer C (Diagram 3) we have 10 knots below 9,000 miles, and 9 knots for longer voyages.

The efficiency of steamer B for a voyage of 4,000 miles would be the same whether she was driven 8 or 12 knots; the same applies to 10 and 11 knots.

Another feature of these curves is that they all refuse to end at zero. If the actual spots were ascertained where the curves would cut the base line, that would indicate the length of voyage where, owing to low freights and comparatively heavy expenditure, there would be no profit. From this we may also draw the conclusion that this size of ship is altogether unsuitable for short voyages; much smaller steamers, probably, being best adapted for such trades. If the curves were extended still further below the base line, it would intersect the Y axis at a point representing, on the same scale, the loss incurred if the ships were laid idle.

The most profitable speed here is in no case less than 9 knots per hour for long voyages; and if the results arrived at by Mr. Hamilton, in the paper already referred to, are now examined, it will be found that for long voyages, in the most cases, 8 knots was the most profitable speed. Of course, there are plenty of steamers built now even, where 8 knots remains the most efficient speed for long voyages; but the examples B and C may be taken as fairly showing the best results that are attained at the present day. It may therefore be taken for granted, with a fair degree of accuracy, that as a consequence of reduced coal consumption following the introduction of the triple expansion engine, the most profitable speed has been increased about one knot per hour.

If now, by means of a successful application of forced draught, or some other means, the coal consumption could be further reduced, the writer feels assured that a more economical speed would be further attained. Having gone into some calculations on the subject, assuming that the boilers, without being increased in weight, consumed only 1 lb.

per indicated horse-power per hour, the freights and the various items of expenditure remaining as at present, the results would be as shown in Plate III., and in comparing these with the diagrams on Plate II., it will be noticed at a glance, without any explanation whatever, that the economical speeds are increased from one-half knot to one knot per hour.

In order to illustrate this more clearly, Diagram 1 on Plate IV. has been drawn, showing the efficiency for 2,000 and 8,000 miles, at various speeds. Along the base line is set off a scale of displacement, and at points corresponding to the displacement of each type vertical lines are drawn, and on these the efficiency marked off to the same scale as on the diagrams on Plates II. and III. Full drawn lines represent the efficiency with the present rate of coal consumption, viz., $1\frac{1}{2}$ lbs., and the dotted lines are drawn on the supposition that the consumption was reduced to 1 lb. per indicated horse-power per hour.

Similarly on Plate IV., Diagram 2, the efficiency of steamer C is arranged with a scale of knots as base line, and curves drawn showing the efficiency for different lengths of voyage. The increase of the most economical speed with reduced coal consumption is here most marked.

For speeds up to about 10 knots the full ship C seems best adapted, but, as has been pointed out before, the amount of indicated horse-power required for this ship at various speeds, compared with other ships built on similar lines, is rather small, so that the efficiency of steamer C is an exceptional case, and other calculations made by the writer seem to favour vessels of somewhat less degree of fullness. The conditions attending trial trips are quite different to the varying circumstances of a long sea voyage. The chances of detention, when steaming against heavy head seas and strong winds, are greater in the case of a vessel built on inordinately full lines and bluff bows.

Cases have come under the writer's notice where the extra profit following the adoption of finer lines has in the lifetime of a boiler paid for the expense of its renewal.

These results, of course, do not apply to every case; they only serve to illustrate the writer's mode of investigation. It is impossible to lay down a hard and fast rule which will hold good under all conditions, but each requirement must be examined and dealt with on its own merits. This paper treats only upon the question of commercial efficiency with varying rates of coal consumption, for vessels known as the three deck type, of a certain size and fixed first cost. It is very often necessary to deal with more intricate problems, such as which type would answer a certain purpose best—spar, well, or three decked ships? But the intro-

duction of so many conditions would be impossible within the limit of one paper, where only examples embracing the main features of the system are given.

Perhaps on another occasion the writer may be permitted to lay before the members of this Institution a continuation of these important and interesting investigations.

It is often the practice to rate the cost of cargo steamers on their dead-weight carrying capacity only. That this is not always the best policy is evident. Some other basis, involving the commercial efficiency, is becoming necessary; and the writer is of opinion that it is only a question of time, that, as the competition becomes keener, some other method than the present will have to be recognised.

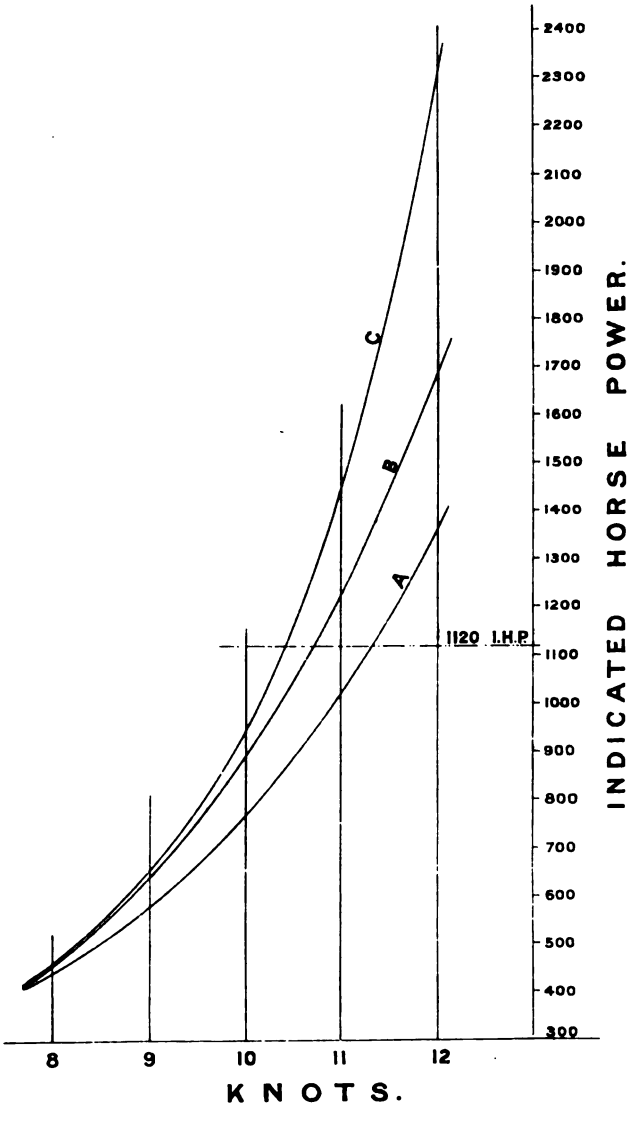
The writer has endeavoured to solve these problems as practically as possible; the rates of freight and the various items of expenditure, being as near what occurs in practice as could be ascertained.

It is to the *combined* efforts of the shipowner, the naval architect, and the engineer, who must unconditionally supply each other with information, that we look with hope to the future. With improved boilers of reduced weight and consuming less coal, and the selection of the most suitable types of ships for a given purpose, even with the present low rates of freights, cargo steamers will pay. New ships will have to be built in place of those which do not fulfil the modern requirements, and we may again hope to have a busy time for our staple industries of shipbuilding and engineering.

DISCUSSION.

Mr. F. J. Trewent was sure they were all much indebted to Mr. Thompson for the very able paper he had given them. They, as shipbuilders, were not very competent to criticise these elaborate figures, and the results arrived at very largely depended upon the expenditure side of the account. He (Mr. Trewent) thought they should have had the two papers together so that they could have discussed the one in the light of the other. The one was a complement of the other, to a certain extent; in fact, in reading over the paper, he had taken it as such, and some of the speeds of vessels given in Mr. Thompson's paper he could not make quite to agree with the data supplied by Mr. Arnison. Mr. Thompson quoted Mr. Hamilton's words to the effect, "that for each vessel and each trade there is a certain speed which is most profitable." Of this he (Mr. Trewent) thought there could be no doubt. Mr. Thompson went on

To illustrate Mr. Robert Thompson's paper on "The Influence of Coal Consumption on the Design of Cargo Steamers."



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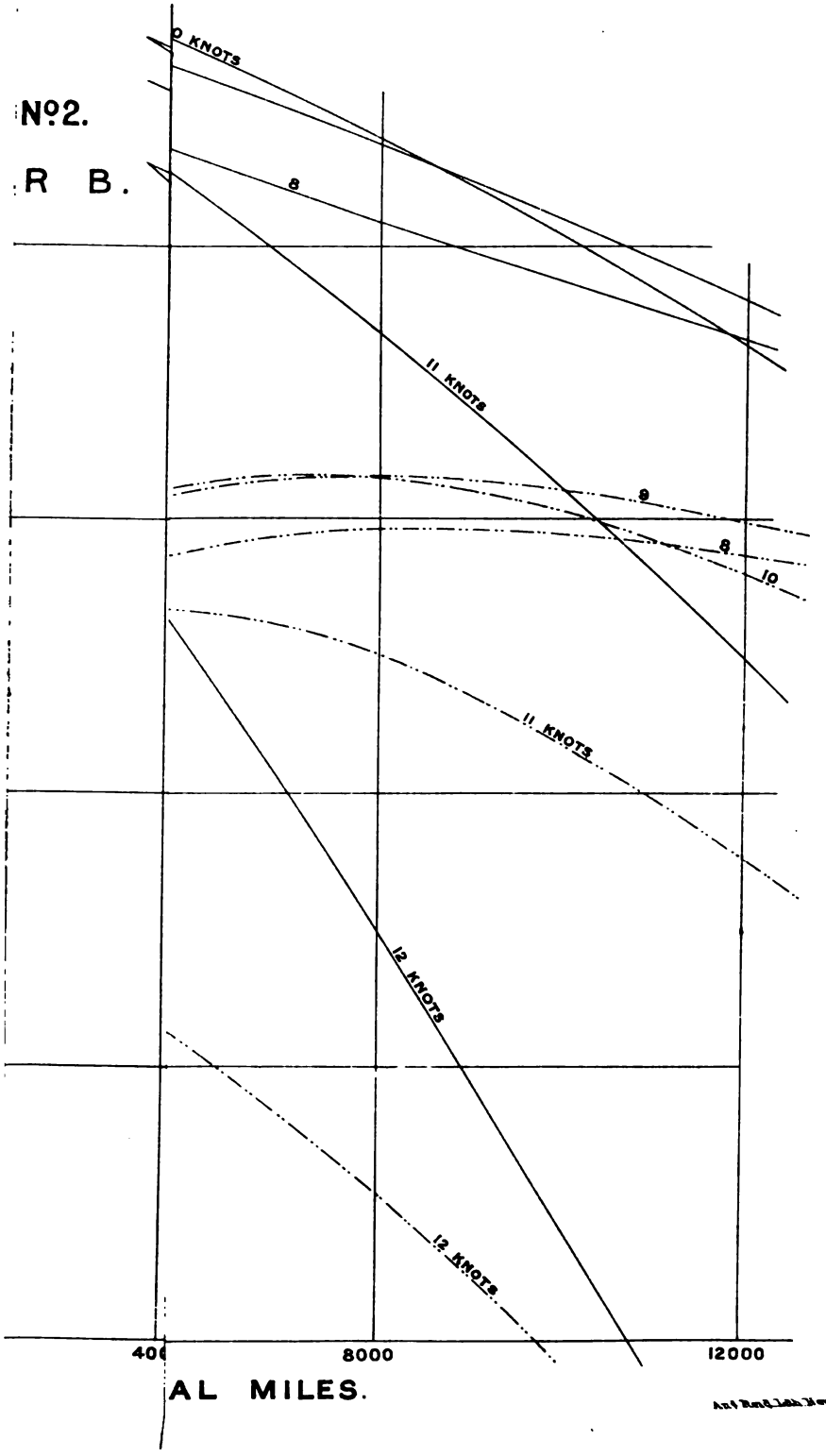
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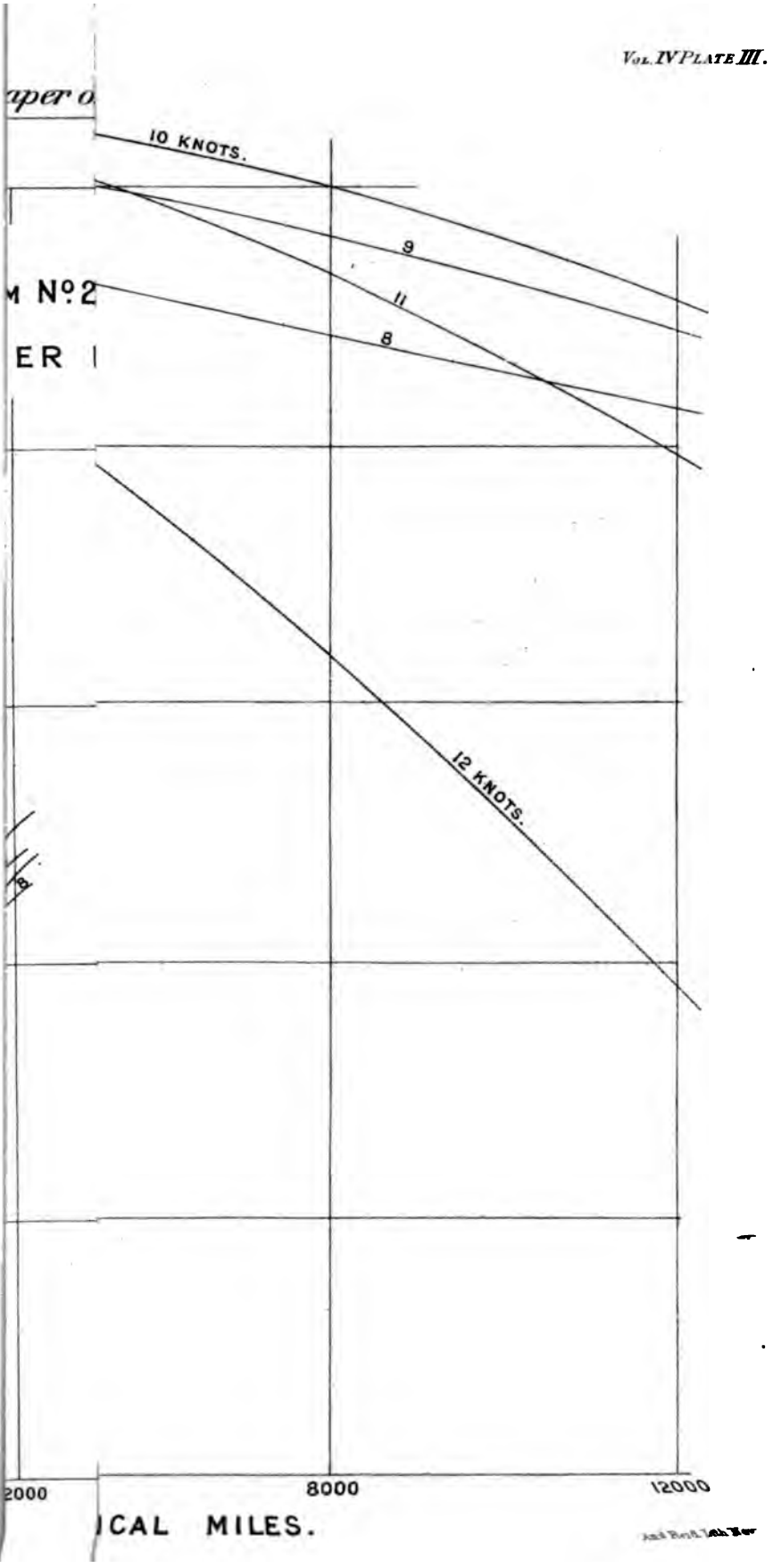
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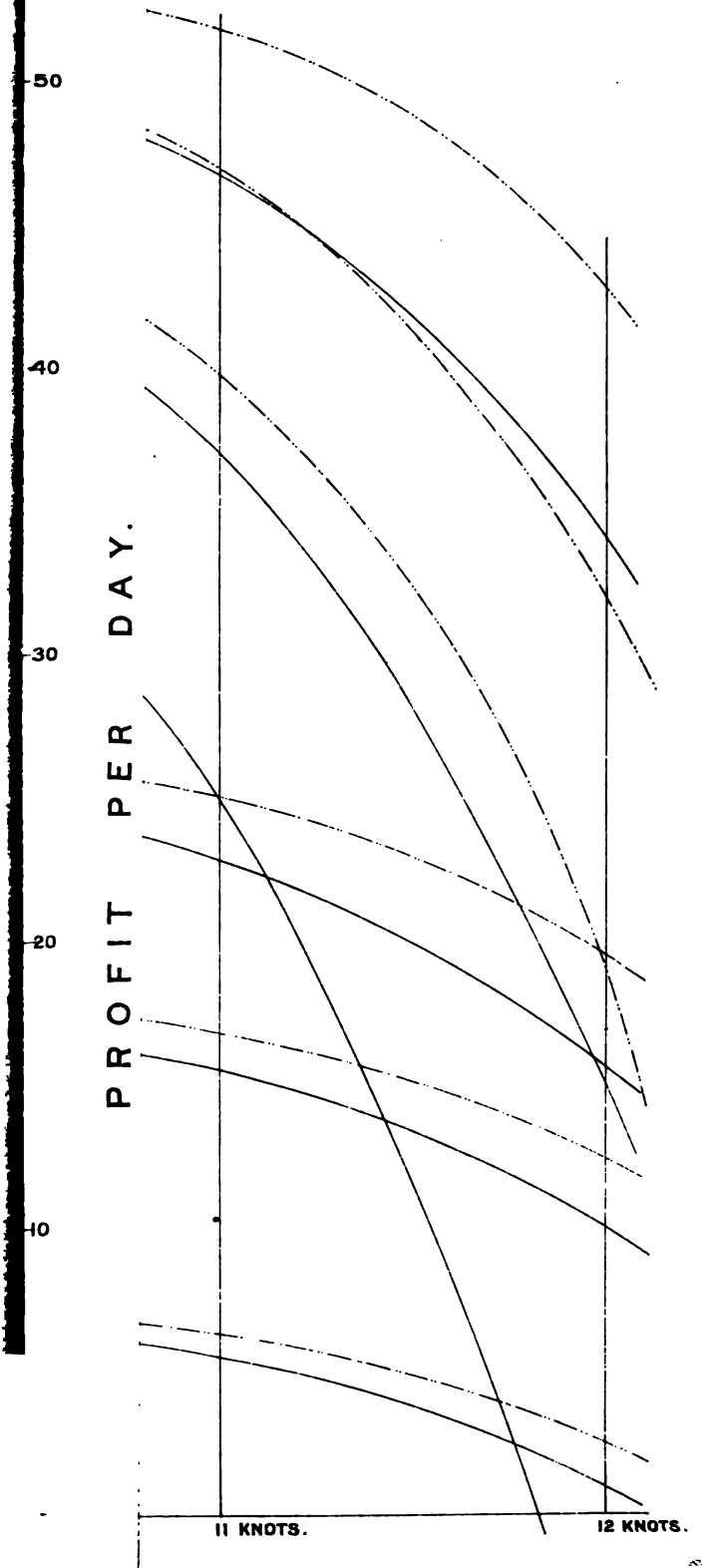


further to say that his firm held the same opinions as Mr. Hamilton :— "That the tendency of building cargo steamers on excessively full lines is a mistake, and they had adopted moderately full lines as being the most suitable for all general cargo purposes." He (Mr. Trewent) would like to know what that meant? It was very vague to say, "adopted moderately full lines." What one man thought "moderately full lines," another might consider not at all full, while a third might say they were very full. So he thought Mr. Thompson in his reply should give them an idea of what he considered "moderately full lines," with the *coefficient of displacement* for the various types. Then he saw Mr. Thompson had calculated the profit on these ships from 8 to 12 knots. Now, if this ship was at all suitable for a 10-knot ship, he did not see how they could calculate profit on that ship going at a speed of 12 knots; for not only as the speed increased did the weight of machinery increase, but the lines were necessarily finer, and various other considerations then came in. He thought the limit, to get any practical result from the comparison, should have been drawn at a knot or so above or below the designed speed. Then, further, these vessels had been calculated for distances up to 8,000 and 12,000 miles. Now, in his opinion, a ship of this size—280 feet long by 36 feet beam—was quite unfitted to take voyages, as a rule, of 12,000 miles. This ship could go very comfortably across the Atlantic, but that was nothing like 12,000 miles. When they looked at this table and saw that the ship Mr. Thompson had built carried 3,100 tons dead-weight, including bunkers, and of this dead-weight on the 12,000 miles' voyage she carried no less than about one-third of it as coal, and only about 2,100 tons of cargo; it was not likely such a ship would pay with that proportionate weight of fuel on board. If they were going long distances they should go in for larger ships, with 5,000 or 6,000 tons dead-weight capacity. Then, Mr. Thompson said that the curve for steamer "C" was the result obtained from an actual progressive trial, and further on, that the steamer "C" represented the "*best result* of any performance of any full cargo steamer he had ever had confirmed in practice," and he thought Mr. Thompson repeated that again in saying that this was "the most *efficient* ship they had built." But "A" and "B" had been deduced, by means of Froude's laws, from ships somewhat larger in actual size, but similar in proportions of fineness. He would take the Admiralty coefficients of these three ships at 10·45, 10·72, and 11·33 knots. From the data given, the 10·45 knots gave a displacement coefficient of 288, which they must all admit a very satisfactory result, and which Mr. Thompson says is his best ship. But when they came to

"B," which did not appear to be an actual ship, they got a coefficient of 301, and when they came to ship "A," with 11·33 knots, they got a coefficient of 330; Mr. Thompson had thus beaten his best ship in these *ideal* ships. He did not know if any of them had any evidence to show that they could get a displacement co-efficient of 330, but his experience led him to say that he had never yet seen it. He thought they had got a third of a knot too much in ship "A," and that they could not expect to get more than 11 knots out of her, while keeping the indicated horse-power constant; that is 11 knots, instead of $11\frac{1}{3}$, and the other one in proportion. Mr. Thompson said:—"In deducing information from progressive speed trials, the results of similar types, when compared, especially if the engines are by different makers, are often conflicting on account of the varying efficiency of the propeller and machinery, and in no case does this apply more than to very full cargo steamers." He (Mr. Trewent) could quite bear that out in two vessels exactly alike, in which they got the displacement coefficient varying as much as from 220 in the one ship up to 280 in the sister ship, simply, he would not say from the efficiency of the machinery, but because one engine ran at a greater speed than the other, the slower one having a little longer stroke and a coarser pitched screw; therefore, the horse-power was much less in the one than the other, and they had got what appeared to be a much higher coefficient of efficiency. On the whole, he thought it a very able paper, and great credit was due to Mr. Thompson for the labour he must have expended in getting such a mass of valuable information together. He, therefore, hoped some of our shipowning friends would throw light upon the financial part of the statement.

Mr. ARTHUR LAING said, he was fortunate to be able to embrace in his person the shipbuilder, engineer, and shipowner, referred to in the third clause of Mr. Thompson's paper, but it was from the latter standpoint he proposed to criticise the paper just read; and, at the outset, he had to say that Mr. Thompson was to be complimented upon the very exhaustive paper laid before the Institution. In the first place, with reference to Mr. Thompson's remark, that "the tendency of building cargo steamers on excessively full lines was a mistake," his experience coincided with Mr. Thompson's, and he would show that this course was justified by results he had before him. A ship which had just arrived at its destination abroad, carrying 3,000 tons all told, had steamed on the voyage out at an average speed of 10·9 knots, her consumption being 18 tons per day, which amounted to 180 tons for the whole passage. Supposing she had been fuller, and had done the voyage in 13 days (conse-

quently at a less speed), at 14 tons per day, the amount of coal consumed on the voyage would have been 182 tons, as against 180 tons mentioned above. Now, if we could take the cost of insurance, stores, portage bill, victualling, and management for the three extra days, which would amount in all to about £16 per day, we would have an economy of about £48 in the three days saved ; but, supposing the slower ship had been fuller, and carried 60 tons more cargo, we would have an increase of freight, less expenses, for this increased quantity, which would amount to, say, £26, showing, therefore, a clear gain of £22 on the voyage for the faster vessel. Well, of course, this was a serious consideration over the lifetime of a vessel, and certainly one which a shipowner, he considered, would lay stress upon. As Mr. Thompson had said, the shipowners were inclined to look simply at the carrying capacity and the cost of the vessel at so much per ton, rather than to lay sufficient stress on the carrying capacity, and take the speed and shape of the vessel into consideration. Experiences like these which he had mentioned above, and the reading and discussion of a paper like that of Mr. Thompson's, would induce them to look more to the shape and speed of vessels, and enable shipbuilders to bring the science of naval architecture to bear more fully on their vessels, rather than as at present the simply turning out of boxes with their edges cut off. On page 66, Mr. Thompson said, "in the same manner the profit per day has been calculated for the different lengths of the voyage at speeds varying from 8 to 12 knots, and the results shown in the diagram on Plate II.;" and, again, in the last clause of page 67 "The weight of the machinery up to the highest speeds, with 1,120 indicated horse-power, has been assumed to be the same, but at 11 and 12 knots the weight has been allowed for in proportion to the required indicated horse-power." He (Mr. Laing) maintained that the same weight ought to be assumed for an individual ship, whether the vessel was running 8 or 12 knots, to give a fair comparison. As regards the tables, he would point out in the first place, that whether the voyage was 500, 1,000, 2,000, 4,000, 8,000, or 12,000 miles, and assuming, as Mr. Thompson had, coal at 7s. per ton, the coal allowed to the vessel for the voyage by Mr. Thompson's tables would only be sufficient to take them 12,000 or 8,000 miles, or whatever the mileage was, and, therefore, to enable shipowners to draw a fair deduction, they ought to have a curve for the return voyage. He had taken the trouble to run out the value of the coals at the other end, *i.e.*, for the return voyage, and supposing a vessel was going 500, 1,000, 2,000, 4,000, 8,000, or 12,000 miles, the values of the coal for the return voyage would be—

Miles.	Price per ton. £ s. d.	Miles.	Price per ton. £ s. d.
500	0 15 0	4,000	1 11 0
1,000	0 18 0	8,000	1 19 0
2,000	1 3 0	12,000	2 2 0

and, therefore, the cost of the coal for the whole voyage would be a mean of the cost of the coal, as taken by Mr. Thompson's tables (*i.e.*, 7s. per ton) and the figures above, and the price of coal would become—

Miles.	Price per ton. £ s. d.	Miles.	Price per ton. £ s. d.
500	0 11 0	4,000	0 19 0
1,000	0 12 6	8,000	1 3 0
2,000	0 15 0	12,000	1 4 6

and the profit per day as per Mr. Thompson's tables would become—

Miles.	Profit per day. £ s. d.	Miles.	Profit per day. £ s. d.
500	5 0 0	4,000	31 0 0
1,000	13 0 0	8,000	15 0 0
2,000	16 0 0	12,000	2 0 0

These figures are taken from the ship "A." The maximum length of a voyage for maximum profit becomes 2,900 miles, with a profit of £32 per day. It would thus be seen that the cost of the coal, as shown by Mr. Thompson, was not strictly in accordance with the case, and more especially so in cases of vessels with high speed, *i.e.*, in the vessels going greater distances, 8,000, 10,000, or 12,000 miles. Supposing, now, they took the 12,000 miles case, where, according to the tables, they had 1,000 tons bunkers on leaving; he pointed out that any ship going this distance in any trade—it might be China or Australia—they would never take that quantity of coal on board, but would call at the various coaling stations *en route*. Mr. Thompson, on page 68, draws this conclusion:—"It may therefore be taken for granted, with a fair degree of accuracy, that as a consequence of reduced coal consumption, following the introduction of the triple expansion engines, the most profitable speed has been increased about one knot per hour." Certainly Mr. Thompson in his tables did show that he had included or considered the price of coal abroad. If he had taken this price into consideration, he would have found, according to his own showing, that the profitable increase of speed would not have been more than one-quarter to one-half knot per hour. The next question he would wish to draw attention to was the question of the speeds, as shown by Mr. Thompson's tables. The speeds given in the tables he took as those obtained on trial trips, and the displacement that of the ship with all her cargo and fuel on board; but the power necessary to

propel the vessel on the voyage must be the *mean* of her displacement. For instance, take ship "C," going a 12,000 miles voyage with 1,000 tons of coal in her bunkers. When she arrived at the end of her voyage she would have 1,000 tons less displacement, and therefore they ought to take the mean of her position, *i.e.*, the mean draught on her departure and her arrival, and the power requisite to drive the vessel should also be taken on that displacement. Now, as regards the expenses, for that was one of the points to which a shipowner paid special attention. He noticed the light dues and pilotage were treated in this paper at so much per ton, whereas, as it would be clearly seen, a collier, going up and down the coast regularly throughout the year, would pay much more for lights per annum than a vessel going out on a long voyage; but, by Mr. Thompson's tables, a large ship would pay more per annum than a small one. Now, this was not the case. For instance, a ship leaving this coast for China, her bills for light dues would be comparatively light as against those paid by a collier in the same period. And as regards the pilotage, this was also dealt with at so much per ton. The pilotage paid by a collier was more frequent, as, of course, she was more frequently in harbour, than in the case of the larger ship; besides, the pilotage, being paid at so much per foot, it is difficult to bring it in the tables to bear any fair relation to the tonnage. Now, as regards insurance, he noticed no insurance was effected on the freight, whereas in the ship "C" it was on the 12,000 miles voyage £4,194, and in the 500 miles voyage £772. Surely, as the shipowner has to insure this freight, there is here also a point for consideration; in fact, as the tables were drawn in the paper, the finer line ships were considerably handicapped. He would be very glad if some member of the Institution would take the subject in hand and treat it exhaustively, and bring out some tables that would be a benefit to the shipbuilders and shipowners, and would enable them to fix upon the model and dimensions of the vessel, and to go thoroughly into the matter, to arrive at the best form and best speed for the vessel they intended building. He trusted that these remarks would be received in the spirit in which they were offered, and *not* adversely, to their worthy townsman, and with a view of elucidating information, and to be of service to the shipbuilders, engineers, and the general public at large.

Mr. W. J. BRANFOOT said, he had had occasion to go into the speed and consumption of a boat with triple expansion engines, and he had found that, supposing the speed was increased, on a voyage of 6,000 miles out and 6,000 miles home, from 8½ to 9 knots, there would be a saving of about three days in time; and if they got a half knot more speed for

about 1½ tons more consumption that was what it should come out. The saving on the standing expense would be £12 a day, and increasing the speed half a knot would leave a net profit of £16, that was, if substantially the same labour, and the same firemen would do the work, and increase the speed half a knot of this particular vessel.

Mr. ARTHUR SCHOLEFIELD thought they, who were shipowners, were under a deep debt of gratitude to this Institution for allowing them to become Associates and have the opportunity of hearing these papers read. They might not be able to follow the technical ones, but so far as they brought out the commercial point of view they were of extreme value. He was only sorry a paper like this was not in their hands a few days before, when most of the shipowners would be in a position to criticise it. He had only the paper in his hands since coming into the hall, and consequently did not feel able to criticise it in the spirit he should like to do. For many of the figures he should want a great deal more explanation before he could say whether he agreed with them or not; and it was from that point of view, and he must say with extreme regret, that it would not be fair to enter into a discussion upon it. He was sure he only expressed the feeling of other shipowners. On the other hand, they felt that one clause in Mr. Thompson's paper was what they wanted to get at. When they wanted to contract for a boat it would be of very great value to them if, instead of merely getting a quotation such as was usual at so much per ton carried, they could carry into actual operation one of Mr. Thompson's recommendations, which was this—they should get some other basis involving commercial efficiency. It was becoming necessary, and the writer was of opinion it was only a question of time. As competition was becoming keener some other method ought to be recognised, and this suggestion was of great value. If they could get a quotation on such basis as that recommended by Mr. Thompson it would be of extreme value, and he only hoped that suggestion would be carried out by steamship builders, and that they would be able to tender upon those lines.

The VICE-PRESIDENT said, perhaps it would meet the desire of the members if they moved the adjournment of this discussion to next meeting.

Mr. SCHOLEFIELD said, he should be happy to do so if this was wished. He had often thought that some of these papers should be adjourned; they were often passed over too quickly; and if they had a chance of studying the contents and allowed to refer to them later on, much more benefit would ensue, and they would show greater deference to the gentlemen who had prepared them.

Mr. J. DUCKITT (Secretary) asked permission to call the attention of the members to the alteration made in Bye-Law 34, which, seemingly, they had not noticed. The Bye-Law in its amended form now gave them liberty to adjourn the discussion on any paper and take it up at the next General Meeting.

Mr. R. S. WHITE said, he rose to second the motion for adjournment of discussion on Mr. Thompson's paper. He thought it was not very flattering to gentlemen who had put themselves to great labour in preparing these papers to see them disposed of in a summary way. He should like to make one or two remarks with reference to the practice which, he hoped, was increasing very much on the East Coast, of not being content with the very summary trials that were usually made on cargo steamers. In the past it was very much the rule, if the weather was fine and everything propitious, to have two runs on the measured mile, and this constituted the bulk of the trial records; and even these were often not taken, by reason of our exposed coast. The performances of such vessels, either on trial or at sea, had seldom been analysed in the way in which they, in a measure, had been dealt with in the paper. He viewed with considerable satisfaction the fact that they were obtaining more information, and most valuable information, in regard to the performances of this important type of steamer. He had had the opportunity during the last few years of trying several of what he thought very full cargo ships through the progressive trials; and the results attained, and shown by the curves, were quite as interesting and valuable as those dealing with vessels of very much greater speeds; and if sufficient care was taken in the engine-room to regulate the revolutions to the exact number required, the results obtained from the progressive trial speed curves would be very valuable for future work. Certainly they had found them of considerable value in designing new vessels. In regard to the question of increased speed for cargo steamers, he quite agreed with Mr. Thompson's remark, that in the adoption of the triple expansion engine and consequent reduced consumption the economical speed at sea was increased, and he joined with him also in the hope that the future would show still greater gains in speed by the use of forced draught, etc., as every day gained on the voyage was money gained. At the same time he looked with considerable doubt as to whether it would ever be profitable to run a purely cargo steamer on a long voyage at a more economical speed than 9 to 9½ knots. He thought, if they went over that, they would have a large coal bill and lose the advantage they would otherwise gain. He hoped shipbuilders, who

were carrying out such progressive trials as that referred to in the paper, would be able some day to lay valuable information as to their results before the Institution.

The discussion was accordingly adjourned till Wednesday, December 7th.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887–88.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, DECEMBER 7TH, 1887.

WILLIAM BOYD, ESQ., PAST-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting held in Sunderland, on November 16th, which were approved by the members present, and signed by the Past-President.

The ballot for new members having been taken, the Past-President appointed Messrs. J. P. Hall and A. Taylor to examine the voting papers, and the following gentlemen were declared elected :—

LIFE MEMBER.

Fox, Samson, The Leeds Forge Co., Limited, Leeds.

MEMBERS.

Carstons, Samuel, c o Messrs. Richardson, Duck, & Co., South Stockton Shipyard, Stockton-on-Tees.

Havelock, Michael, Commercial Chambers, Side, Newcastle-on-Tyne.

Moody, Thomas V., c o Messrs. Ernest Scott & Co., Close, Newcastle-on-Tyne.

Newitt, Leonard, c o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne.

Parsons, Hon. Charles A., Elvaston Hall, Ryton-on-Tyne.

Ruthven, M. W., c o Messrs. Wigham Richardson & Co., Walker-on-Tyne.

ASSOCIATES.

Branfoot, W. J., Messrs. Tyzack & Branfoot, John Street, Sunderland.
Dryden, H. F., 4, Quayside, Newcastle-on-Tyne.

GRADUATE.

Gaine, Roger L., 17, Park Place E., Sunderland.

The adjourned discussion on Mr. R. Thompson's paper "On the Influence of Coal Consumption on the Commercial Efficiency and the Design of Cargo Steamers" was then resumed; after which Mr. E. F. Wailes read his paper "On Improvements in the Construction of large Stern Frames, Rudders, and Keels."

ADJOURNED DISCUSSION ON THE INFLUENCE OF COAL CONSUMPTION ON THE COMMERCIAL EFFICIENCY AND THE DESIGN OF CARGO STEAMERS.

The PAST-PRESIDENT (Mr. W. BOYD)—who intimated that he had received a note from Mr. R. S. White, who had seconded the adjournment of the debate, regretting his inability to attend that night—said, that before calling upon Mr. Scholefield, who moved the adjournment of the debate, he should just like to point out that he thought the gentlemen present at Sunderland the other evening hardly remembered sufficiently the alterations made in the bye-laws. Mr. Duckitt, the Secretary, referred to it; but he thought he hardly put it sufficiently strong. If they referred to Bye-Law 34, it would be found that while, as in the case of Mr. Arnison's paper, Mr. Arnison having replied, the discussion was closed; that the discussion on any given paper is *ipso facto* open for renewal at the subsequent meeting. The bye-law in question, which was altered at the closing meeting of their last session, namely, in May of this year, reads as follows :—"The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting prior to the reading of the paper set down for that date." Of course that was done; but the alteration was made with the view of effecting what Mr. Scholefield moved for, without going through that formality, so that the discussion on any paper should be open for renewal at a subsequent meeting.

Mr. A. SCHOLEFIELD, in resuming the discussion, said, when he moved the adjournment of this debate in Sunderland, he must confess he had not the slightest idea that he should be called upon to open it that evening. He did it at the request of the Vice-President, Mr. Coote, for it was evidently the sense of the previous meeting that the discussion on Mr. Thompson's paper should not then be closed, because the majority of those present, like himself, had not seen the paper until they had entered the room, and he thought it would have been a mistake to close the discussion without giving to Mr. Thompson's paper that attention which it

merited. He (Mr. Scholefield) had not had the slightest intention of saying anything more on the subject himself, but of giving shipowners resident in Newcastle an opportunity of speaking to the meeting. However, having been called upon, he would venture to make some observations upon the paper before them. He found, to take the clauses *seriatim*, that Mr. Thompson, in the second clause of the paper, says:—"Shipowners pay considerably more attention now than formerly to improvements in the vessel's proportions, machinery, and outfit, in order to secure the highest possible economy for the requirements of the trade for which the vessel is being built." That was decidedly the case. The severe depression through which they (shipowners) had passed induced economies in every possible respect, economies in the working expenses day by day of their steamers, and economies in any new vessels, both in their design and equipment. He looked upon this state of things as one of the most important for the benefit of an institution like this; for the depression had made them so alive to the necessity of improvement, that they were on the outlook for it, and the inventive genius so well displayed by the members of this Institution would, he was sure, be called into requisition. Mr. Thompson said, with regard to the proportions of steamers (see page 66), that he held the same opinion as Mr. Hamilton, namely, that the tendency to build cargo steamers on full lines was a mistake, and moderately full lines best for all general purposes. If he might be allowed to say so, he thought that the expression, "moderately full lines," was a decidedly Gladstonian phrase. It was capable of bearing that wide interpretation which we had gradually accustomed ourselves to give to phrases from the eminent controversialist named. He must say, he thought it would be more accurate to say that there were many purposes for which full ships had been, and would be, used. For instance, there were vessels trading to light draught ports, where a certain length of ship could not well be exceeded, and where, on the other hand, it was necessary in a vessel of that kind to carry the largest possible cargo; and under those conditions he believed it would be found that very full ships would be built. Amongst their own fleet of steamers they had one with a coefficient of ·826, and another with a coefficient of ·803. The ·803 corresponded in one respect very nearly to the vessel "C," which Mr. Thompson described; but their vessel, being very much lighter draught than his, was, of course, proportionately fuller. Well, he thought their experience of those ships was, although not in favour of *extraordinarily* full lines, yet that for light draught purposes, for which they were constructed, they certainly were a

success. Therefore, in regard to Mr. Thompson's clause, even although he evidently meant it to bear what he (Mr. Scholefield) termed a Gladstonian interpretation, he would say he did not make sufficient allowance for certain exceptional cases in which full ships were required and of great value. He had been looking at the vessels, "A," "B," and "C," described by Mr. Thompson in the table facing page 66, and found the greatest possible difficulty in comparing steamers of 2,315 tons, 2,910 tons, and 3,131 tons, in regard to their profit or earning power; for, he thought, there could be no doubt, from the shipowner's point of view, seeing these vessels were all practically of the same dimensions and draught, that, of course, the 3,131 tons boat would be far the most profitable; and the only way to compare such vessels would be, if the smaller boat had been constructed with such a lighter draught as to enable her to go to ports where the others could not have gone to, and so obtain higher freights. Under those conditions the 2,315 tons vessel might have been the most payable of the three. Coming to the question of consumption, he had re-read what Mr. Laing said at the Sunderland meeting, and certainly could add very little to it, Mr. Laing's remarks being very much to the point. He should like to hear what Mr. Thompson had to say in reply; but in regard to light draught boats, they could not deal with them with the same uniformity as they could with deep boats. Their instructions to captains were practically these:—If you get into fair weather, drive as hard as you can, irrespective of a certain increase in the consumption; and in rough weather, slow down; because with light draught boats the propellers were readily thrown out of the water, and to drive ahead meant racing the engines for no good. They found they got in this way a fair average in regard to the speed. With regard to the artificial draught, they were all, of course, paying the greatest attention to it, as a means of economy. One great advantage of the artificial draught being the uniformity in regard to speeds, whether the vessel was steaming with a strong head wind, or trading, for instance, in the Mediterranean, in possibly a dead calm. By having a uniformity of speed they would increase their average considerably. Then, in reference to what Mr. Thompson said on page 70, with regard to the practice of rating the cost of cargo steamers on their dead-weight only, and suggesting another basis involving the commercial efficiency. It was a very good suggestion indeed, and probably the time would come when shipowners wishing to build new vessels would be able to apply to steamship builders and obtain an offer and specification of a steamer in such a way as would involve its commercial efficiency, a method they could not very well do at present. This was all

he had to say. He must apologise for the very meagre addition he had made to the discussion, but hoped his remarks would be received with that indulgence which he had always found the members of this Institution bestowed upon those who addressed them.

Mr. G. E. MACARTHY said, he must ask their indulgence for addressing them. He had not had the opportunity of studying the paper thoroughly. He had only had it in his hand for the last few hours, and therefore he could not deal with the various paragraphs so very ably as Mr. Scholefield had done; but he had had the opportunity of reading the discussion on the paper, and he should like to give his ideas on the subject. The question of "moderately full lines," which Mr. Scholefield had described as being a Gladstonian expression, he could quite understand the doubtfulness of, if Mr. Scholefield assumed that his vessel of a coefficient of ·826 was a vessel of "moderately full lines." He said that was a decidedly Gladstonian way of putting it, according to Mr. Scholefield's application of the term "Gladstonian," with which he (Mr. Macarthy) did not agree. He (Mr. Macarthy) said it was exceedingly full. He supposed the object of Mr. Thompson's paper was to arrive at almost an utopian object; he wanted not only to be the shipbuilder and the engineer, but he wanted to be the shipowner too. He (Mr. Macarthy) thought it was the shipowner's province to decide for himself what sort of ship he wanted. During the last few years they had had a very great influx into steamship owning—he was sorry to say, very detrimental generally to the interests of shipowners—by many men who practically knew nothing about it; and he doubted very much whether it was advisable to arrive at that state of perfection in which any one could go to the shipbuilder and order a steamer and have it exactly the right thing for the trade he fancied. He could understand it would be very important to have (for the shipbuilder to have) data by him so as to construct a ship suitable for any particular trade. The question as to which was the most economical rate of consumption and speed was a very important one. He had taken some little trouble to work out the results of a new steamer they had recently built, and he thought, as the results were not unfavourable, he need not make any apology to the builder if he gave the name of the steamer. He alluded to the steamer "Gem" as the type of steamer properly described as being of "moderately full lines" for general cargo purposes. Her dimensions are:—280 feet between perpendiculars; breadth, 38 feet 8 inches; depth, from top of beam to top of ordinary floors amidships, 19 feet 5 inches. Her coefficient of fineness is ·766; triple expansion engines with cylinders 21½ inches, 36 inches and 59 inches diameter, by 39 inches stroke. Steam is supplied by two multitubular steel

boilers, each 13 feet 6 inches long by 9 feet 6 inches diameter, heating surface 3,200 square feet, having three furnaces each, 3 feet 3 inches diameter. On her trial she indicated nearly 1,100 horse-power; initial steam pressure, high-pressure cylinder, 160 lbs.; intermediate cylinder, 60 lbs.; low-pressure cylinder, 9 lbs.; vacuum, 28 inches; revolutions, 62; displacement, 4,500 tons. She was now on her first voyage from the Tyne to Bombay, and the results ascertained so far showed that she had a speed of 9 knots on a daily consumption of best North-country coals for bunker purposes of 15 tons; but he was led to believe that he should be able to effect an improvement when she returned home. She was loaded with a cargo of 3,150 tons of steam coals, all told, on a draught of 20 feet mean. Taking the Bombay trade as a fair average of the general cargo trade, they might assume that the distance from the Tyne was 6,480 knots (it was rather more), and, taking the speed at 9 knots, they had exactly thirty days' steaming. The price of the best Tyne coals for their steaming purposes was 7s. per ton; at Port Said it was 20s. per ton. Take, also, the basis of freights on the round at 40s., which was the present rate. The annual cost of insurance, wages, provisions, and stores, and say 5 per cent. per annum for depreciation, might be taken at £5,475, or £15 per running day. This might not be exactly correct, but it was quite near enough for his purpose. He found from experience that the most economical coaling arrangement, in the Bombay trade, was to take a sufficient supply of coals from the Tyne to Bombay, and filling up at Port Said outwards and homewards; thus avoiding the higher-priced coal at the other side of the canal. Taking these figures for data, and assuming for the sake of argument that by building a steamer of finer lines than the "Gem" the carrying capacity was reduced by 145 tons and the speed increased 1 knot. She carried 3,150 tons, all told; of that she had—

Cargo, 2,700 tons at 40s.	Leaving £4,792 10s. to pay other expenses.
Bunker coals, 450 tons at 7s.	
Port Said bunker coals, out and value, 450 tons at 20s.	
Days' steaming, 60	
Freight carried, £5,400	
Cost of coals, £607 10s.	

Taking off 145 tons and increasing the speeed 1 knot they had :—

Cargo, 2,600 at 40s.	Leaving £4,743 5s. to pay other expenses.
Bunker Coals, 405 tons at 7s.	
Port Said bunker coals, out and home, 405 tons at 20s.	
Days' steaming, 54	
Freight earned, £5,200	
Cost of coals, £546 15s.	
Six days saved at £15 per day = £90	

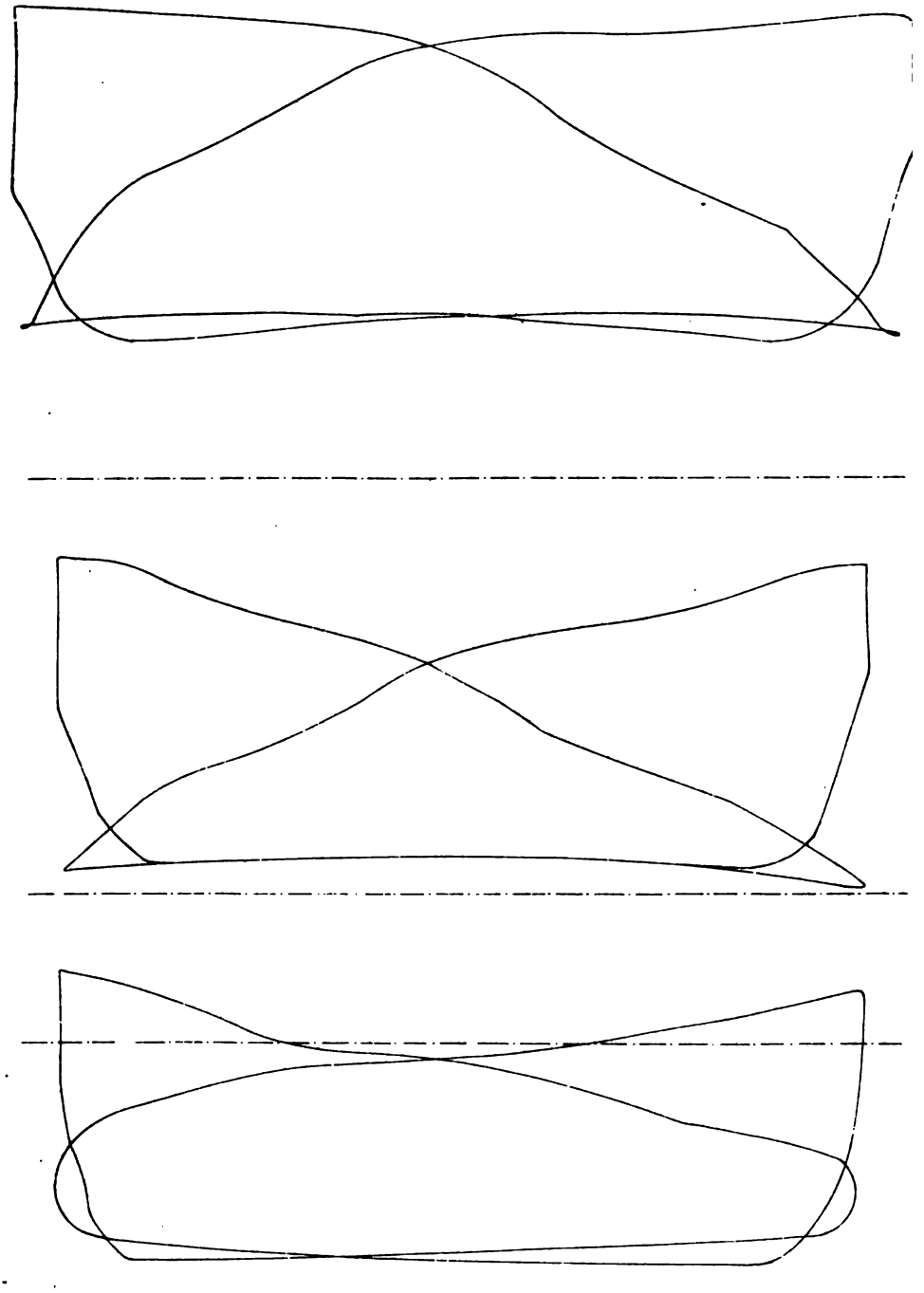
A difference of £49 5s. per round voyage in favour of the slower steamer. He had assumed the increase in speed on the reduced carrying capacity without any data before him, and Mr. Thompson would, no doubt, be able to put him right if he had gone far out. Now, let them take another view, and suppose that without reducing the carrying capacity they increased the power; and, that by an extra consumption of three tons daily, the steamer could be driven 10 knots in place of 9 knots, there would be this result for the three tons daily consumption; he should have to pay extra cost of coal, £48 12s., and lose on freight, £72, against a saving of six days' time = £90.

Cargo, 2,664 tons at 40s.	Leaving £4,761 18s. to pay other expenses.
Bunker coals, 486 tons at 7s.	
Do. Port Said, 486 tons at 40s.	
Days' steaming, 54	
Freight earned, £5,328	
Cost of Coals, £656 2s.	
Six days saved, at £15 per day = £90	

It was quite clear that he had arrived (as he thought), at the most economical mode of working combined with consumption and speed, and he failed to see any difficulty that should arise to any other shipowner in working out the same thing. Mr. Thompson probably could explain why it was necessary they should have these tables laid down for the use of shipbuilders and shipowners. He (Mr. Macarthy) failed to see the necessity of it.

Mr. D. B. Morison said, that during the discussion of Mr. Thompson's paper, at the last meeting, some of the results from the ships, used by him as examples, were considered as somewhat exaggerated. As all these ships were engined by Messrs. Richardson & Sons, he had much pleasure in confirming the accuracy of the figures relating to the speed coefficients. The observations on deck were taken by Mr. Thompson's trained staff, and the time carefully checked by chronographs. The indicator diagrams were also taken by a specially trained staff from Messrs. Richardson's works, and the power calculated from the mean of three sets taken on the mile. With regard to the actual results, those marked A are deduced from a ship which gave on progressive trial an Admiralty coefficient of 316 for a speed of 12·05 knots. Upon working out the figures given in Mr. Thompson's paper, he found they corresponded to a coefficient of 323 for 11·33 knots. The results marked B are deduced from another vessel similar in dimensions, but with fuller lines than A. This ship gave on trial an Admiralty coefficient of 301 for a speed of 11·22 knots. Mr. Thompson's figures correspond to a coeffi-

To illustrate Mr. D.B. Morison's remarks on Mr. Thompsons paper.



S. S. "C," *in Table.*

I.H.P.	H.P.	367
"	I.P.	348
"	L.P.	405
"	TOTAL	1120

STEAM 150 REV^{s} 71 VAC^{m} 27.

cient of 301 for 10·72 knots. The results marked C, are those actually obtained from a steamer of the dimensions given, but with still fuller lines than B; the speed and horse-power being those actually obtained on trial. The corresponding Admiralty coefficient is 289 for 10·45 knots. He had handed Mr. Thompson a tracing of the mean of the diagrams taken on this trial (see Plate V.) The performance of the last mentioned steamer, although described by Mr. Thompson as "the best result of the performance of any full cargo steamer they had had confirmed in practice at sea," was not the best performance of any cargo steamer obtained on progressive trials. He might mention as an instance a steamer 300 feet long, with a prismatic coefficient of ·768, built by Messrs. Thompson and engined by Messrs. Richardson, which gave on trial an Admiralty coefficient of 337 for 9·95 knots, and for 11·575 knots a coefficient of 314. These coefficients being from the displacement over the skin as given in Mr. Thompson's paper. These results were not exceptional but corresponded to those usually obtained in those of Messrs. Thompson's boats, which they had engined; and he had no doubt that similar results had been attained by other firms. Mr. Thompson had told them that for each trade, there was a ship, and a speed which will give the most profitable results; and, from an engineering point of view, he thought this might be extended to fitting the ship with the most profitable machinery. By this he meant that for each vessel and each speed, there was a certain number of revolutions of propeller, proper to that speed. Mr. Barnaby in his treatise on "Propellers," showed this to be the case, and found by experiment the most efficient propellers for certain speeds and powers, and from these deduced the propellers for all other speeds and powers. The great misfortune was that all his screws worked in undisturbed water, and the results would have been considerably different with a full cargo boat, with a block coefficient of fineness of, say ·77. Nevertheless he was convinced that for each boat at each speed and power, there was a suitable propeller, and a suitable number of revolutions. The number of revolutions would determine the size of the engine; and if they had the results of numerous experiments, curves might be constructed similar to Mr. Thompson's, from which it would be seen to what extent the cost of the engine would modify the calculations regarding the efficiency of the ship.

Mr. T. McNAB said, he had not the pleasure of being at the last meeting when the paper was read, nor had he within the last few days had an opportunity of reading the paper with a view to making any very special remarks upon it. He had simply to say, in reference to this question, as to what was the most economical type of vessel for any given

trade, he thought it was one well worthy the consideration of shipowners particularly, as well as the shipbuilders and engineers. Like speed, which they understood was to be obtained at a sacrifice, the economical working of a vessel depended upon a number of conditions, not only of speed and the consumption of coal, but upon the management. They all assumed, shipowners at all events were quite certain, that the management was perfect—(A voice—"We are")—but like engineering and ship building, it required a good deal of experience and a long training. From the various trades a vessel might be employed in, the results of these various trades could only be arrived at by long experience; and it was not from mere theories and a presumption that they could do this or that with a vessel placed in their hands. But, he wished to say, that the paper brought forward by Mr. Thompson was one that would have very useful results in directing people's minds to the points therein raised and discussed. He was not prepared, nor did he wish to say anything further than to thank Mr. Thompson in person for the paper he had read.

Mr. D. STEPHENS had not intended to say a word on the subject, however, after the few remarks made by his fellow-shipowners, he thought he should like to express his views. In the first place, he quite agreed with Mr. Thompson that the future ships for speed and economy should be built on finer lines. From what he had seen, he had come to the conclusion that very few shipowners knew what shape of a ship they wanted; all they asked the builder for was a cheap dead-weight carrier, and the builder, in order to compete with his neighbours, was compelled to build a box. He often wondered how they steered at all; however, they appeared to get along at sea very well, but, in entering docks and narrow channels the continual damage done, both to ships and pier heads, clearly proved the steering qualities to be very indifferent. He had been connected with ships since he was nine years of age, yet he knew little about the modern ship, and he was quite sure many managing owners knew very much less; however, his idea of a good ship was, full forward and fine aft. His experience both with sailing ships and steamers was, that a sharp bow meant a wet ship, and, in a head sea, if not eased, everything would be washed off the decks. A full bow prevented this plunging, and with a fine after-end the vessel steered much better, and he believed the speed increased as the propeller worked in more solid water. Most certainly, many of the shallow boats now running steered very badly, and he would strongly advise his brother shipowners, when building, to insist on a finer after-end. If they gave more scope to the builders, he was positive of this, they

would not build ships in the future like those built in the past. He quite agreed with Mr. Thompson, and was glad he (Mr. Thompson) had brought this matter forward, that too little attention had been paid in the past to the shape of ships; and, as far as he was concerned, he begged to thank Mr. Thompson for his able paper.

Mr. H. Macoll said, to those who had been engaged in the construction of those structures which by courtesy were called steam ships, but of which a considerable number of the ordinary cargo carriers more closely approximated to rectangular boxes than anything ship-shape, it was decidedly cheering and refreshing to find, in the paper which had just been read, a clear and decided note being sounded against the too frequently adopted mode of designing sea-going vessels on the principle of the greatest dead-weight on the least possible dimensions. There can be little doubt that for a considerable time the popular idea has been to make each successive "ocean tramp" rather fuller than her predecessor. Given a vessel of certain dimensions and dead-weight capacity, the owner's friend, competitor, or possibly himself, in the succeeding vessel, stipulated for somewhat more dead-weight; the result being, vessels which rolled fearfully, were difficult to steer and handle, and of very slow speeds, even in fine weather, while in rough weather and head seas, the onward progress was scarcely perceptible. In order to secure the best results it was very desirable that more frequent communication, than the ordinary trial trip, should be held between those who owned and sailed the steamer and those who constructed them; for if after that all went well the builder scarcely received any further information, and it was only when some mishap took place that it was remembered that shipbuilders and engineers were in existence. It is not too much to say, that, in ascertaining the actual results of vessels' behaviour at sea under different conditions of weather and lading, the shipowner would not derive the least of the benefit by getting the best results of past experience thoroughly digested and analysed. The writer of the paper does not refer so much to the financial results of the vessels as to their carrying and steaming capacity, together with the amount of coals and engine stores consumed; the other outlays incurred in working the vessel such as harbour dues, etc., not being a matter much under the control of the constructors. The paper read by Mr. Thompson was a very able one, and must have entailed a very large amount of work, first collecting the information, and then arranging and working out the results as indicated by the tables and diagrams; and it was not the least merit of the paper that it indicated, by extending and contracting the distances and speeds from the normal

ones obtained in good practice, how unsuitably steamers might be employed. It occurred to the speaker that, by looking at the figures from another standpoint as it were, the results might be made more graphic, and the differences perhaps more easily compared; that is, taking the basis of comparison as the capability of the value of one pennyworth of coal in carrying or propelling a ton weight a certain distance. As illustrating this take steamer A. The gross dead-weight, including bunkers, was carried at the rate of 353 to 344 mile-tons for one pennyworth of coal; and the same vessel, taking the net cargo—that is, freight earning cargo—carried on the short distance 347 mile-tons falling to 204 mile-tons at the longest distance. Steamer B, on the gross, 421 to 412 M.T., and on the net 416 to 270 M.T. Steamer C, gross 431 to 433 M.T., net 425 to 290 M.T. The details of each speed and distance are given in the following tables. He believed that something like 500 mile-tons could be attained; but of course it could only be done in much larger vessels than those indicated in the tables. And on the other hand, the saving in coal on the voyage could easily be lost by a small detention, waiting on the large cargo that would be necessary; and the tendency would be to prolong the "dead life," as it was termed, of the vessel. This, however, was a matter that could only be arrived at by experience.

TABLE.—Mile-Tons per Pennyworth of Coal.

Steamer A.

	500	1,000	2,000	4,000	8,000	12,000
Gross dead-weight ...	353	344	344	344	344	344
Net „ ...	347	333	321	299	251	204

Steamer B.

	500	1,000	2,000	4,000	8,000	12,000
Gross dead-weight ...	421	411	411	413	412	412
Net „ ...	416	399	387	366	317	270

Steamer C.

	500	1,000	2,000	4,000	8,000	12,000
Gross dead-weight ...	431	430	431	433	432	433
Net „ ...	425	419	407	386	337	290

Mr. R. THOMPSON said, that before replying to the different speakers, he would preface his remarks by saying that the profits shown in the paper were only meant to exhibit the *comparative* efficiency between different types, with varying speeds and coal consumption, and not to indicate what was possible to do under all the varying circumstances that accompany the practical management of cargo steamers. The displacement coefficients given in the paper were the *prismatic* coefficients, *i.e.*, the product of the length and midship area divided into the displacement, which, of course, is the truest measure of a vessel's fineness.

Mr. Trewent spoke of the paper as being a complement of Mr. Arnison's paper. He thought anyone who had read the two papers would agree with him that they treated on different subjects entirely. He had not seen Mr. Arnison's paper until a couple of days before it was read, and did not previously know the nature of its contents.

With regard to the definition of the expression, *moderately full lines*, —the discussion of which, by the way, nearly drew from one or two of the speakers a confession of their political faith—he quite agreed with some of the speakers that there was a wide difference of opinion, and he could only answer for himself in saying that the steamer C represented the fullest lines adopted by his own firm.

Mr. Trewent said that "he did not see how they could calculate profit on that ship going at a speed of 12 knots, for not only as the speed increased did the weight of machinery increase, but the lines were necessarily finer, and various other considerations then came in." The extra weight of machinery necessary to drive these ships at 11 and 12 knots was allowed for, which was also stated in the paper. This had, by-the-bye, contrary to Mr. Trewent, been criticised by Mr. Laing, of which he would say more further on. The object of the paper was, to a certain extent, to show what relation the profit bears to the fineness of the ship and length of voyage. This size of vessel was by no means recommended as suitable for as long voyages as 12,000 miles; in fact the diagrams show that the most profitable trades, under certain conditions, for this steamer was about 3,000 or 4,000 miles. He thought, it was generally agreed amongst shipowners, that for long voyages the largest ship the nature of the trade would permit was the most profitable one.

Mr. Trewent seemed to judge the efficiency of steamers solely by the Admiralty speed coefficients, and from that point of view had thrown some doubt on the figures given for speeds and powers. It must not be forgotten that the value of these speed coefficients varied with the speed, and it would be well to state that the maximum displacement speed co-

efficient of the actual steamer A was 326 at 11 knots, for steamer B 312 at $9\frac{1}{4}$ knots, and for steamer C 322 at $8\frac{3}{4}$ knots. The vessels from which data had been obtained for these calculations had all been engined by Messrs. T. Richardson & Sons, of Hartlepool, and he could assure Mr. Trewent that with their engines they had frequently had as high coefficients of performance as those stated.

They were always careful to give accurate information, and he was very grateful for Mr. Morison's corroborations and able statements.

He begged to thank Mr. Laing for the friendly remarks and the criticism he brought forward. It afforded him great pleasure and satisfaction to know that his (Mr. Laing's) varied experience in the capacity of shipbuilder, engineer, and owner agreed with his own experience in the main points. With regard to Mr. Laing's remarks about the weight of the machinery, his first intention, when framing the calculations connected with the paper, was to allow for the weight of machinery in proportion to the indicated horse-power necessary to drive the three vessels 12 knots; but after due consideration, the machinery of the actual steamer C was taken for the three vessels, and extra weight allowed for 11 and 12 knots. If he had assumed the weight of machinery from the 12 knot power, the full steamer C would be handicapped, compared with the finer vessels, in having to drag a considerable amount of unprofitable dead-weight about at the lower speeds; and he trusted Mr. Laing would take it as a compliment when he said that he (Mr. Laing) would very likely have been the first to find this out, and criticise him for it. He was very glad that Mr. Laing had touched upon what he might term *possibilities* of the return voyage, with its varying prices of coal and other items of expenditure, because, although he could not admit that, by means of the figures with which he (Mr. Laing) had favoured the Institution, he had altered the conclusions arrived at in the paper, he had merely given an illustration of the difficulties that have to be contended with in making calculations of this kind. In similar calculations he (Mr. Thompson) had, in individual cases, taken account of the return voyage, but found it too varying to introduce into the paper. Especially in long voyages the return freight was governed mostly by the outward freight, and *vice versâ*. He would repeat again that the object of the paper was to show the comparative and not the real profits. This would be noticed if the table was referred to; where, for instance, could be found a steamer of this size which would be able to earn £50 per day at present? Before any comparison at all could be made the vessels must be considered under like conditions. If the diagrams on Plates II. and III. were

altered to suit the rates of coal expenditure given by Mr. Laing it would be found that, although the magnitude of the profits was changed, the curves would retain a similar character, and thus still prove that, with reduced coal consumption, the economical speed would be increased to the same extent, as shown in the diagrams. Formerly the coal was the heaviest item of the expenditure; now it was the wages and provisions, except perhaps at shorter voyages where the stevedoring was most expensive; and in proportion to the increased coal consumption at the higher speeds a number of extra firemen were allowed for. Mr. Laing put down as a positive fact that the necessity of coaling at various stations *en route* was indisputable. Well, he knew for a fact that shipowners at large held somewhat divided opinions on this subject. Take, for instance, a vessel sailing to Odessa. If loading in England it might perhaps be most profitable to take in sufficient coal supply for the whole voyage, but if sailing say from Antwerp it would be advisable to coal during the voyage. Of course this all depended on the trade, freight, and price of coal at the various stations. In some long trades there was no chance of being supplied with coal, except at the port of destination. It was true no allowance had been made with regard to coal consumption on account of the difference in draught between the beginning and end of the voyage, but the error involved in this was not great. Take as an example the steamer C at 4,000 miles. There would be a difference of the displacements between the beginning and the end of the voyage about 344 tons, and the difference in horse-power at 10·45 knots about 40 indicated horse-power. This would reduce the mean coal consumption per day during the voyage to 17·7 tons, and the total consumption to 281 tons instead of 287, or a difference of 6 tons. Six tons coal at 7s. per ton reduces the expenditure £2 2s. Increase of freight for 6 tons extra cargo at £1 per ton equal to £6; thus the extra profit amounts to £8 2s. on a voyage of 4,000 miles, or about ½ per cent. of the net profit. In similar manner, for a voyage of 12,000 miles the error would be about 3 or 4 per cent.; but then nothing was allowed for the constantly changing condition of the bottom, which, perhaps, if it could be taken account of, would cause as much *decrease* in the profit. It was almost hopeless to attempt to deal with all such minor details, except in a summary manner, and if Mr. Laing would only favour the Institution with a method whereby could be ascertained the varying influence on the coal consumption by not only the variations in draught, but also the conditions of the bottom, and the ability of the few firemen usually carried in cargo steamers to do

efficient work for long periods in hot climates, then he for one should hail that with the utmost gratitude, as it would be an exceedingly valuable aid to all who attempted deducing information from ships' log books. Mr. Laing was evidently assuming that the ships were always sailing from a home port. Pilotage was paid in some places on the tonnage and sometimes on the draught. In most Continental ports no light dues were paid—in fact, England, he was afraid, was about the only civilised country where light dues were paid at all. The expenses under this heading had been calculated on the register tonnage and deduced from a number of ships of about the same size. Mr. Laing had criticised him for not taking into consideration any insurance on the freight, but the question might also be asked, how should a fair comparison be made? In longer voyages the freight was often paid in advance, and then of course no such precautions were necessary as insuring the freight.

In reply to Mr. Scholefield, he would point out that what had been said about the most economical speeds also referred to light draught cargo steamers, namely, that for each steamer there was a certain speed which would be most profitable for a given trade. If Mr. Scholefield had his ships tried progressively on the measured mile, to ascertain correctly the relation between speed and revolutions, and then—say on a voyage—the coal consumption corresponding to varying number of revolutions, he would be able to predict more closely the most profitable speed for a given voyage, which was never in any cargo vessel the highest speed the engines could drive her at. Of course there were exceptions to every rule, and the saving of time and other considerations in certain trades that could only be got at by experience, which would modify the theoretical economical speed, and justify Mr. Scholefield in giving the instructions mentioned to his captains. Mr. Scholefield was no doubt correct in considering the steamer C the best from an owner's point of view, as far as the particulars went in the paper; but supposing Mr. Scholefield had a new steamer built of the same size and displacement, he might be unfortunate enough in getting a set of engines and propeller altogether unsuitable for the ship, accompanied, of course, by a proportionate decrease in the profit. Speaking from a wide experience in building all kinds of cargo steamers, he (Mr. Thompson) would say that it was only a very rare occurrence to have a full cargo steamer as efficient with regard to economy as steamer C. A vessel of the same displacement as C, but less draught, would take more horse-power to drive than C, so that he was rather inclined to differ with Mr. Scholefield when he said that very full ships would be an advantage if the draught was limited.

He would not dispute with Mr. Macarthy the shipowner's right of "deciding for himself what sort of ships he wanted," but he had been trying to point out in the paper the growing necessity of more conference between the owners and builders. Unless they worked together the steamers would never be perfect, whether considered as money-making articles or works of art. He thanked Mr. Macarthy for the information he had given; but thought, however, that the increase of speed of the "Gem," as estimated by Mr. Macarthy—if that steamer was made finer by the amount of 145 tons—was much overstated. In working out the profits for these two ships in a voyage to Bombay and home again, Mr. Macarthy had not taken account of the time spent in harbour. In order to make a comparison, the profit per day, as well as the total profit, should be known for the whole time occupied. Assuming, therefore, that the total time during which the "Gem" earned £4,792 10s. was 92 days, the profit per day would be about £52. With 145 tons less dead-weight capacity, and, for the sake of argument, assuming that they could get 10 knots, the total time occupied would be about 85 days, and this, divided into the profit, viz., £4,653 5s., gave nearly £55 per day, or about £3 per day in favour of the finer vessel. From this, of course, had to be deducted all other expenses, such as wages, provisions, insurance, pilotage, etc. To drive the "Gem" 10 knots, he thought, would take at least 4½ tons more coal per day than at 9 knots. He had simply in this paper thrown out a hint to show what might be gained if proper attention was paid to running steamers at their most economical speeds, and in giving the shipbuilders a chance of assisting with their knowledge and experience, when the dimensions and proportions of new steamers had to be fixed upon. The table was only intended as an example of what had been achieved, and could, no doubt, be improved upon. It was for each individual shipowner to apply his own judgment, and he was certain that the owners would not lose anything if they sometimes heeded the advice given by builders who tried to keep pace with the advancing science of shipbuilding.

Mr. Stephens and Mr. Macoll had touched upon the sea-going qualities of full steamers; and with regard to the steering, he had himself repeatedly noticed how slow very full ships were in answering the helm, more especially if they were light. The superior steering qualities of the steamer B, compared with that of steamer C, was most marked.

In conclusion he had to thank them for the way in which the paper had been received. It was not intended by any means to be a perfect paper. He was much gratified by the discussion they had had upon it,

for that was really the first object he had in view to hear different expressions of opinion upon what had been said before the Institution. He must say that he felt amply repaid for the work it had taken to prepare this paper in finding that shipowners were, as a rule, willing to agree with him that there was a necessity of predicting more than the dead-weight capacity in relation to the first cost of a new vessel. More time and care would be required when estimating, in which the owners themselves must take a considerable part.

He was much indebted to the staff in the employ of their firm for working out the calculations, and especially thankful to Mr. J. Johnson, Chief of their Scientific Department, for his assistance.

The PAST-PRESIDENT wished to mention one small matter regarding the paper now before them which had not been noticed by any of those present, that, excepting the papers from Mr. Cameron on Forgings and Mr. Arnison on Speed Calculations, they had had no other paper from a Sunderland member. He was quite sure those who had heard Mr. Thompson's paper, and taken part in the discussion, would join with him in saying it was one of the most valuable papers they had had since the Institution was opened. He only hoped some of Mr. Thompson's brother townsmen would follow his example, and that these may only be the beginning of a series of papers from a neighbouring port. He asked them to pass a vote of thanks to Mr. Thompson for his most interesting paper.

This was carried by acclamation.

IMPROVEMENTS IN THE CONSTRUCTION OF LARGE STERN-FRAMES, RUDDERS, AND KEELS.

By E. F. WAILES, M.I.N.A.

[Read before the Institution, December 7th, 1887.]

The following paper is offered for the consideration of this Institution, with the object of bringing under its notice what the writer considers to be valuable suggestions with reference to improvements in the construction and formation of Rudders, Stern-frames, and Keels in navigable vessels, but more especially in the case of large merchant steamers.

Attention is drawn, in the first place, to the subject of Rudders and Stern-frames, and later on reference will be made to ships' Keels. But before doing so, it would be well to point out some of the detrimental features said to exist in their present form of construction. We are all aware that during the rapid progress of iron shipbuilding, the size and tonnage of steamers laid down for the mercantile marine have increased year by year, and there is no reason now to suppose that we will not continue to go on building vessels of a still larger type than hitherto: hence the importance of giving some consideration to the stern-frames and rudders, which are becoming of such enormous dimensions and weight, without what may be considered a proportionate or adequate increase in strength.

The necessity of having stern-frames and rudders of sound and reliable materials, cannot be too carefully observed by those interested in the construction of our mercantile navy. It is well known to the members of this and other similar Institutions that the present mode of constructing stern frames, either by solid forgings or solid castings, contains many objectionable features which need to be eliminated. Important improvements are required before they can be deemed reliable, or entitled to that claim to perfection which is absolutely and imperatively necessary to ensure the safety of the ship and lives at sea.

The chief objections to forged iron frames are their inevitable welds, which are necessarily weaker than the solid forgings they connect. It has been found that large ships encountering heavy seas on Atlantic

voyages have, in many cases, had their stern-frames broken, owing to imperfect welding. Such accidents became so numerous that the Committee of Lloyd's Register, some four or five years ago, appointed practical surveyors at various ports throughout the country to ensure the forgings being efficiently welded. This action on the part of Lloyd's is to be commended. It must have borne fruit, and doubtless many calamities may thus have been averted. However, the evil is not yet cured, and serious accidents will continue to occur, until the necessity for welds in the construction of frames; the bulky nature of these huge heavy frames of solid section; and the scanty and inefficient fastenings they admit of to the main structure of the ship, which are at best but flimsy connections, for want of a proper junction on to the transom frames, floors, and stringers, can all be avoided. Nor can it be considered satisfactory, that such an important part of the ship as the stern-frame, should be devoid of the means of being thoroughly incorporated into the hull of the ship, more especially when it is remembered that the frame has to bear the weight of the rudder, and, in addition to that, the screw, tail-end shafting, and stern-tube, which, in some cases, amount in all to over eighty tons. The solid bulk of these massive frames, or deadwood (if it may be so termed in connection with an iron ship) that is hung on to the extreme end of the vessel, is naturally the cause of an increased impetus to the vibration, resulting from the screw exerting a sideward pressure on the boss of the stern-post through which the shaft works.

The surest way to minimise accidents is to lessen vibration. This desirable object could practically be obtained, provided deadwood was abolished, and some additional strength and buoyancy imparted to that sharp part of the ship, the ends or run, adjoining the stern-post. This refers, more especially, to ships of fine lines. To do this the ends, or run, would have to be thicker, which would give the required buoyancy and admit of the frames and floors being carried down to the keel their full size and dimensions. Without adequate buoyancy and strength at this part, the vessel becomes dependent upon the outer plating; and, under certain conditions, where there is violent vibration, the strength of the riveted joints is seriously endangered.

The nature of the stern-frames should be more in unison with the main structure of the hull, which can only be effected by reducing their rigidity and imparting to them some degree of elasticity. In this way, the relationship between the frame and the hull would be more compatible with satisfactory and safe results.

Some four years ago, the writer was under the necessity of placing an iron steamer in dry dock for the purpose of repairing the rivets and fastenings of the tuck plates, which were severely damaged in consequence of the vessel meeting with heavy seas and bad weather during an Atlantic voyage. After the plates were removed the stern-post was discovered to be broken square off at the foot of the rudder trunk (see Fig. 4, Plate VII.) clear of any welds, and at a solid part of the post. The inner and outer posts were also fractured at the welds, each about 2 feet 6 inches above the sole. The rudder main-piece was broken about half way up. It need hardly be said the frame was taken out. The vessel was built considerably over the requirements for Lloyd's highest class. This damage should not have happened, had there been less rigidity and no welds in the stern-frame. The writer is of opinion that the fractures would be caused by the inability of the heavy forged frame to give to, or work in harmony with the hull, under the severe strains which the vessel would be subjected to in such heavy seas.

Cast steel stern-frames and rudders have all and more of the disadvantages appertaining to bulk and weight than the forged frames. They certainly are without welds, but the scarphs are very cumbrous and weighty; they have more efficient connections for fastening the frame to the structure of the ship. They are better in some respects, but in others not so good as the forged frames, while, owing to their bulk, permanent repairs cannot be effected.

There are not many things connected with the construction of vessels which are of much greater importance than the manufacture of stern-posts. They may be looked upon as an important subject for the careful consideration of scientific investigators; and it is hoped manufacturers who may be present this evening, will not view these remarks with disfavour in this humble endeavour to attain a form of frame that will do justice to the labour expended upon it, and end the trouble and expense incurred both at home and abroad.

The writer will now proceed to explain his views for securing "greater efficiency in the construction of Stern-frames and Rudders." Assume you are dealing with a steel screw-steamer of the following dimensions, viz.:— 263 feet long, 36 feet in breadth, and 23 feet in depth of hold.

Fig. 1, Plate VI., represents a stern-frame of I girder section, moulded and cast in mild steel, having vertical flanges on the outer and inner posts, which look forward and aft. These are continued throughout the frame, in which the various sections are increased or diminished for such distribution of strength as may be considered necessary. To counteract

the bending *moment* of the sole piece, additional bulb webs are introduced longitudinally, likewise transversely. (See Section B.) The frame is cast in three separate pieces, thus avoiding injurious contraction from unequal masses of material in cooling. In this way the frame can be more quickly made; also admitting of the use of smaller ladles and boxes. It is jointed together with long tapered scarphs, situated above and below the boss, and in the middle of the after-post. This frame can be easily transported, and, in the event of serious damage, the injured piece conveniently taken out and a new one substituted. In the case of slight damage, there should be no difficulty in effecting a substantial repair, while temporary repairs abroad could be managed with ease, simplicity, and at small cost. The gudgeons are of steel, riveted on to the outer posts between the vertical flanges. (See Section C and Fig 1.) The web of the girder section is 12 inches deep, and the width over the flanges 10 inches, and 1 inch thick. The thickness varying throughout to bear a similar breaking strain as a forged iron stern-frame, which it is estimated would be attained with a saving of about 25 per cent. in the weight, and a proportionate reduction in the cost of manufacture. The inner post being so much wider, makes the run, or ends of the ship considerably thicker, thereby increasing the buoyancy and rigidity of this part by admitting of the full strength of frames and floors being carried down to the keel. The frame is thoroughly fastened and incorporated in the hull of the ship by the inner flanges being connected and riveted to all the floors, frames, stringers, and decks adjoining; the shell plating being riveted through the outer flanges, and, if need be, through the inner flanges. There being no deadwood (if the term may be applied) in this instance by this form of construction, it will more effectually resist the straining when the vessel is labouring in heavy seas. The water lodged between the vertical flanges prevents a lateral motion, and counteracts the vibration, assuring steadiness, and attaining the desired harmony between stern-frame and hull. Should it be considered an advantage, suitable fenders can be fitted between the lower flanges of the sole piece, so as to resist, in a measure, the shock caused when striking the ground.

Fig. 2, Plate VI., represents a Rudder of cast steel, on the same principle as the stern-frame of I girder section, moulded to the various sizes that may be required for the efficient distribution of strength. As in this case there are no very unequal masses of material to contend with during the process of cooling, it is better made all in one piece, so that if the rudder should at any time be seriously damaged, the injured part

could be cut out, and suitable scarphs then formed to receive a duplicate piece. In vessels with deep sterns, the stock can be scarphed outside of the rudder trunk, to admit of the rudder being easily unshipped. The main piece is arranged so as to admit of portable pintles being fitted of wrought steel and *riveted* to the main piece—for uniformity of material—(see Section D and Fig. 2), which are carefully turned to suit the gudgeons upon the stern-post, so as to be readily adjusted. The rudder head is lengthened in a forward direction an equal distance before and abaft the line of the centre of the pintles.

This part is fitted with a suitable liner of brass, or other metal, to work inside of an anti-friction bearing which is placed upon a wrought iron bed, as shown on Section E. It will at once be seen that the increased size of the rudder head gives a greater resistance to the vibration, causing the rudder to work smoothly. A square shoe is cast on the top of the head to receive the tiller, and the shoe piece can be carried higher up if necessary to suit a screw steering gear. The wrought iron bed could be easily opened out, as the top is movable, being only bolted. This arrangement prevents any possibility of leakage through the deck, as is often the case where the ordinary stuffing boxes are in use. The inner side of the bow and the inner side of the main piece have only single flanges, which are continuous with three stiffening stays, all of which have holes drilled throughout, to receive the rivets which connect the plating, fitted on each side of the web flanges and stays, as shown on Fig. 2 and Section D.

This form of rudder can be made of the same strength as one of forged iron, with the advantage of being about 25 per cent. less in weight. The water lodged induces rigidity and steadiness, reducing the strain on the structure of the frame, and the friction on its working parts.

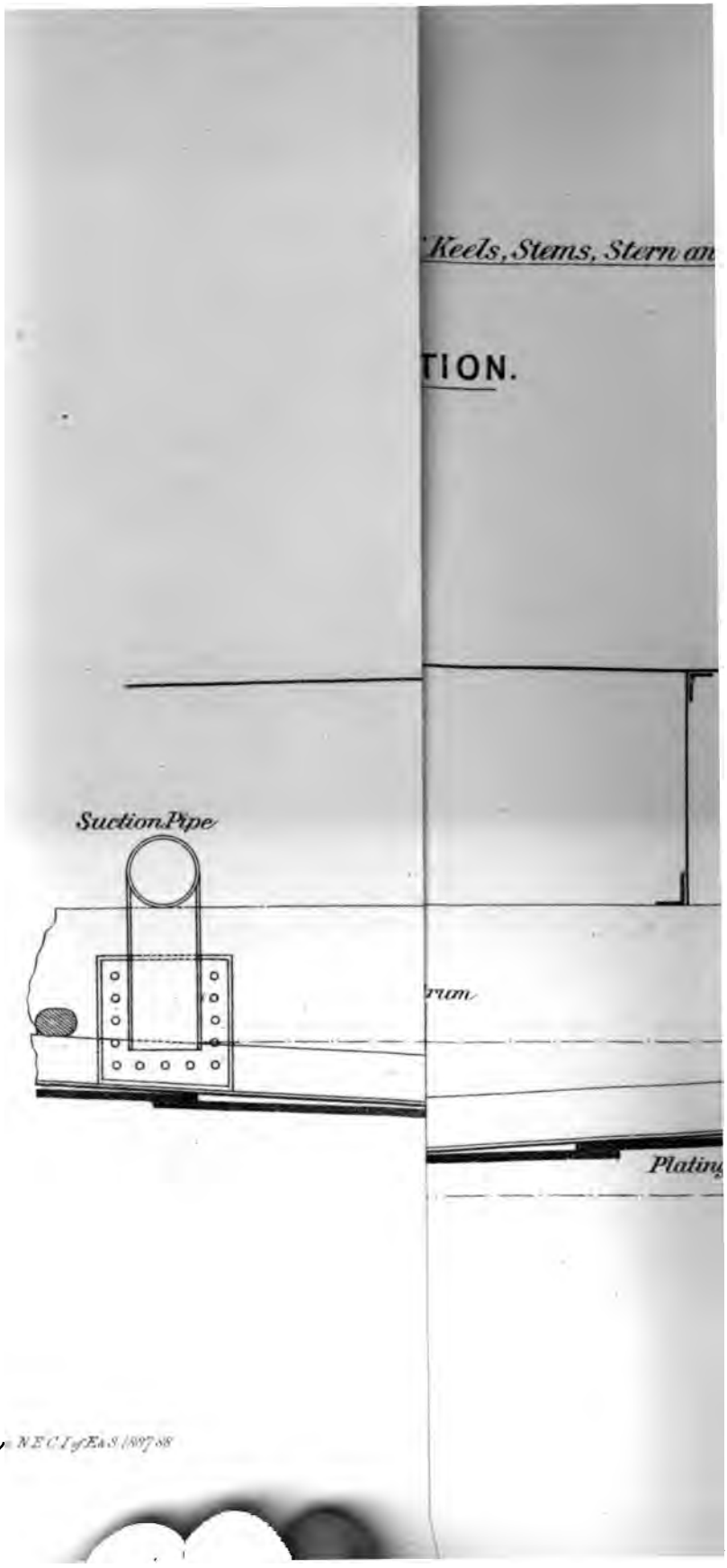
Figs. 3 and 4, Plate VII., represent an alternative mode of constructing Rudder and Stern-frames on the ⌶ girder principle; that is, instead of making them of cast steel, they would be composed of wrought iron or steel ⌴ channel bars, riveted back to back; this system being carried throughout, without any *solid bar combinations*, excepting the boss, pintles, and gudgeons. The boss is made of cast steel, fitted to the frame, as shown on Sections F and G, with long flanged tail pieces introduced above and below, between the vertical flanges on the after side of the post, securely riveted through the web and flanges. In addition to fitting the boss piece, as described, the flanges of the two channel bars are smithed and carried round the outside of the boss while hot, and by this means contracted tightly on to the casting. The sole piece, as shown on Section H, is strengthened by fitting angle or ⊤ bars from the inner to the outer post,

completely debars any examination or effectual cleaning operations inside of the bottom and bilges. The only real remedy for this evil is to have the suction or drain pipes *below* the bottom of the ship, instead of *above* it as at present; therefore, the only part of the ship that is below the flat of the bottom being the keel, and it being solid, does not admit of the pipes being taken below, consequently, to attain this object, it would be necessary to make the keel of a hollow or channel form, which has not yet been successfully introduced into ships of large tonnage. It is a common practice to have channel keels in small steamers when light draught is of some importance. Channel keels, of a plate construction, welded together in short lengths, or with butt straps inside, were tried in larger vessels some years ago, but, owing to their impracticable nature, they were found to be objectionable, and their use was discontinued.

Fig. 5, Plate VIII., represents the full-sized section of a U channel Keel—which is $8\frac{3}{4}$ inches deep by $8\frac{1}{2}$ inches wide, the side flanges being each $1\frac{1}{4}$ inches thick, and the bottom $1\frac{1}{2}$ inches thick—composed of rolled steel, which it is proposed to bring under notice, with the object of overcoming the difficulties to which reference has been made. It is in long lengths, the same as the ordinary bar keel, with spigot and faucet scarphs, machined to fit closely together, as shown on Section L, Plate IX. (and full-sized working model), which admits of the removal of any one length in case of damage, just as in a bar keel. The garboard strakes are riveted through the side flanges, which is effected by hand, or, in the case of hydraulic power, a suitable tool can be used, so as to slide along the inside of the keel, for the purpose of inserting and holding down the rivet. It is connected with the stern-post, as shown on Section M, Plate VI., and at the forward end is curved and continued to the sheer line so as to form the stem. Or it can, when necessary, be adapted to scarph into solid stems and stern-frames.

Fig. 6, Plate IX., shows the Bulkhead, which is continued into the keel by a T piece of iron frame, joggled on to the ordinary frame. The latter being stopped short on each side of the centre. The pipe represented is for draining purposes, led down into the keel, and effectually protected by perforated plates, forming a strum. The usual suction pipes are fitted at each bilge, as shown on Fig. 7, Plate X., for taking out the water in the double bottom. The line A indicates the level of the bilge water remaining after the ship is drained, under ordinary circumstances. The line B is the level attained by the channel keel. The weight of water between those levels is estimated at 40 tons.

With total elimination of bilge water, there should be no necessity for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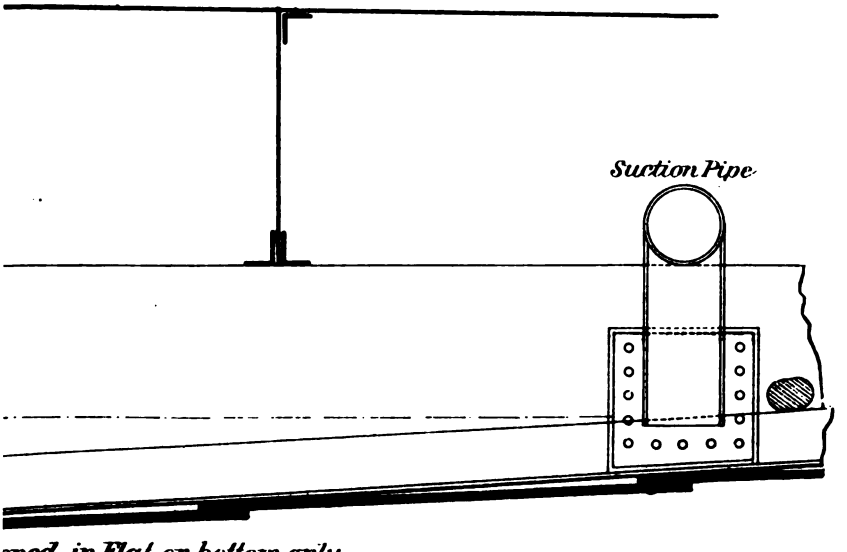

xped in Flat or bottom only.

Art Rep. Lith. Newcastle

Mr. E. F. WAILES said the ordinary solid bar keel would be about half an inch deeper—9 inches by 2½ inches—the channel keel 8½ inches by 8 inches. It was therefore about the same depth, but 5½ inches wider than the present keel.

Mr. GEO. N. ARNISON, Junior, expressed the opinion that the paper was a valuable one. As to the adoption of the suggestions of Mr. Wailes, the Classification Societies referred to in the latter part of the paper would possibly raise difficulties. He concurred in the preference given by the writer of the paper to cast steel as a material for stern-frames in lieu of wrought iron girders. Already cast steel stern-frames have been employed, but it was now proposed by Mr. Wailes to make an important departure, and he submitted a valuable one, more especially as regards large vessels. The writer of the paper had, however, not pointed out one of the important advantages that stern-frames constructed as proposed in his paper had over the ordinary solid castings or forgings, viz., the facilitating of the riveting of the shell plating to the stern-frame. He (Mr. Arnison) had seen, and no doubt others present had seen, stern-frames of steam vessels in which rivets as long as eighteen and twenty inches were necessary. It was a very difficult task to make thoroughly sound riveting under such circumstances. Turned rivets and tapped bolts had been sometimes adopted, but not always with satisfactory results. Now, in the stern-frames as proposed by Mr. Wailes, the shell rivets would be of the ordinary lengths, and it was therefore natural to expect the riveting would be much more reliable, in fact, as good as in any other part of the vessel. The question of bilge water was a most important matter brought forward in the paper. No doubt, if possible, the whole of the bilge water should be pumped out of all vessels, and it was an object worthy of accomplishment. The proposal of a hollow keel by Mr. Wailes, appeared to be leading them to that desired end. He (Mr. Arnison) however, would point out that if a vessel fitted with the proposed keel had a permanent list, it would be impossible to pump it dry by means of the central bilge water trough as proposed. Something more was required for getting the bilge water properly out of the modern sea-going vessel. One of the principal difficulties was the position of the limber holes, the lower side of which are usually not less than three inches above the skin of the vessel, and in large steamers as much as seven inches. This difficulty was primarily owing to the depth of the frames, the limber holes being cut through the floor plates immediately above the frames. It had been attempted to overcome the difficulty by forming drain holes about two

inches long and one inch deep, close to the keel of the frame angle-bars, but practical men knew these holes were a deception. If not fouled before the vessel left the shipbuilder's hands, the slightest accumulation of mud, which would accumulate in bilge water, choked the "drain holes." To keep them clear would require continual attention, and at the best with but unsatisfactory results. If some plan could be adopted whereby the limber holes proper could be lowered, it would undoubtedly be advantageous. At the Liverpool Exhibition, 1886, there was shown by a Malmo shipbuilding firm, among the Bureau Veritas exhibits, a midship section of the paddle steamers "Korsor" and "Myborg," in which they had succeeded in lowering the limber holes according to the drawing, by joggling the frame angle-bar up in their wake. It might be possible to effect the same object, and by the same methods as scupper holes on a weather deck are formed in the gunwale angle-bar, to clear the water out of the waterways. No doubt if shipowners were speaking out and telling shipbuilders they must build their vessels so as practically to have no bilge water that could not be pumped out, shipbuilders would be able to overcome all the difficulties. It might slightly increase the cost of a vessel owing to the probability of compensation being required for cutting the frame bars, but seeing that in ballast tanks, etc., frames were cut at the bilges, it could scarcely be said that the idea of lowering limber holes was impracticable. Again, in cellular bottomed vessels, if the longitudinal system of framing was carried out to a greater extent than it has been in such cases, a ready means could be obtained for lessening the amount of bilge water. Certainly the question of bilge water was one requiring attention, but as it had only been mentioned incidentally in the paper, possibly he might have been out of order in speaking at such a length on the subject. In concluding, he (Mr. Arnison) thought it would be agreed by all present that the principal subject brought before them in Mr. Wailes's paper was of great interest, and in his (the speaker's) opinion, the cast steel stern-frame, as described and illustrated in the paper, was a great advance upon the ordinary cast steel stern-frames hitherto manufactured.

Mr. R. H. TWEDDELL wished to know whether, in the event of a vessel thus constructed taking the ground, if the author's section of keel would be as strong and take the strain as well as an ordinary bar keel? In the ordinary bar keel any upward strain would be resisted by means of the intercostal keelson, but, in the case of the keel on the diagrams, all the strain would come upon two, practically speaking, knife edges, and tend to shear the floors at the point of contact. It struck

him as being, to a certain extent, a much weaker arrangement. It also occurred to him that the author, by still further widening the plates, could make the keel form the bottom or garboard strakes. This would give a large bearing surface, and no longer have the keel supported by rivets subject to a shearing strain. In reference to the clearing of the bilge water, he thought the writer's proposals most ingenious, and he should think, from his own experience, that they could be carried out. The stern-frame design, so far as its suitability for getting the riveting done, was a good one. Of course it would all be very much better done by machine.

Mr. R. THOMPSON said that Mr. Wailes had mentioned the fact of a forged stern-frame or cast steel frame being more rigid. He had only considered the paper as Mr. Wailes was reading it; but it struck him that the words "rivet" and "riveting" were very often brought in, and it was just a question to his mind whether, in a frame of this kind, considering the amount of riveting and the way it was placed, they could get the same strength; and whether this frame, instead of having the fault of being too rigid, would be perhaps too weak? He should have liked Mr. Wailes to have given them figures, showing the proportion of strength of this frame as compared with the forged frame, especially in that point mentioned by Mr. Tweddell with regard to the keel. He saw Mr. Wailes had fallen into the more common style of frame. The distance from the boss to the top of the frame was very much greater than from the boss down to the keel, and he thought by so doing, the attachment to the top of the frame was of a very meagre description. He was speaking from his experience, where frames having the same kind of attachment to the shell plate, as shown, weakness had set in. (Here Mr. Thompson illustrated his point by reference to Fig. 1, Plate VI.) They were now bringing their frames so that at the top of the propeller very little space was left, and the attachment to the shell plate was much more efficient than in the fine narrow space. Mr. Wailes mentioned tuck plates; it was very long since they did away with them altogether. In frames where the fineness of the lines did not admit of the frames going down, they swelled the lines out in order to get the proper attachment, and more efficiently carry the frame. Mr. Wailes also remarked, that members of Classification Societies might take an interest in his designs. He (Mr. Thompson) quite agreed with Mr. Wailes in the difficulty there was in getting an expression of opinion from those Classification Societies to which he referred. They would only take into consideration questions of this kind when they had a *bonâ fide* ship put before them

and a *bonâ fide* owner. They would not otherwise give an expression of opinion, although all the information in regard to strength might be given to them; they would not look at it unless it was for a ship actually to be built, consequently, notions of this kind were sat upon and thrown back. Where they had had a new system, longitudinal system instead of vertical, sent to Lloyd's, it was returned with thanks. Mr. Wailes mentioned a saving of £30 on cement. He should like to ask him whether he meant Portland cement or the new enamel cement?

Mr. WAILES—Portland.

Mr. THOMPSON—Then he (the speaker) thought it would not be saved, for shipowners took enamel, as it was much lighter and possibly as good otherwise. The idea about the bilge water seemed to be following what they had in sailing ships, a centre way running fore and aft for the water to be drawn into. If this could be carried out it would be an advantage to shipbuilders and shipowners. He should like if Mr. Wailes would furnish them with the strengths of these frames as compared with the ordinary forgings.

Mr. D. STEPHENS said, as they, the shipowners, often got capital hints from shipbuilders, he thought the builders would not refuse a hint from him. Twenty-five years ago the builders in the West of England did away with pintles (he was speaking of ships in which he served). The stern-post was hollowed out and the rudder post made to fit into it. The rudder was stepped in the keel, and had no other support, with the exception of a landing in the head of the rudder trunk. His experience of these rudders was all that could be desired, and he did not see why pintles should be fitted to ships of the present day, which required continual re-bushing. As to the hollow keel, if it could be made strong enough, he thought it would be a great benefit to shipowners, as the difficulty at present was to get clear of all the water ballast. He remembered many years ago building a ship in Sunderland, and whilst loading she tumbled from one side to the other. He first blamed the trimmers, but it turned out to be the water in the tanks. The ship was only fitted with a middle strum, which partly explained the difficulty of getting the water out and the listing from side to side. If the tanks and bilges could be drained off to the keel it would be a boon to shipowners. He believed every water ballast ship carried unprofitable cargo in the shape of water in the tanks, which the present arrangements could not possibly get rid of, and they who went down to the sea in ships knew the danger of water in the bottom, especially with a shifting cargo; it made bad worse, and he, therefore, considered Mr. Wailes' idea an excellent one, and would like to see it adopted.

Mr. W. Boyd (Past-President) said, before closing the meeting he should just like to make a few remarks upon Mr. Wailes' paper as he was a very old friend of his. He must endorse what one of the speakers had said that he thought it was certainly a step in advance, and one, as Mr. Thompson said, which deserved to be encouraged. All these steps in advance made very slow progress; it was only by perseverance and inherent merit that they ultimately became part of their ordinary practice. This question of stern-posts was one that, perhaps, some of those present might know had a great deal of personal interest to him. It was a matter in which he had a good deal of experience; but, at the same time, if they could imagine a ship repairer looking at a thing of that sort from an unprejudiced point of view, it did seem to him an unpractical and unreasonable necessity that obliged the amount of work to be performed that was necessary in a broken stern-post, when perhaps all the cause was a slight crack down in the heel of the stern-post. Of course the existence of that crack might indicate a more serious defect. Sometimes it did, sometimes it did not; but there were occasions when, for a very slight cause, a very large expenditure of money and detention of valuable property came about. He (the speaker) was not a shipbuilder and could not criticise the new stern-post from a shipbuilder's point of view; but it seemed to him that if Mr. Wailes, or any other gentleman, could, by the adoption of steel in pieces like that (for it seemed to him that the essence of the whole thing lay in these scarphs), provide that accident in any particular part would not necessarily condemn the whole of the stern-post, a very great advantage would be gained. He thought they were much indebted to Mr. Wailes, and other gentlemen who in a similar way brought forward any well-considered novelty of this kind, and he was glad to think it was one of the outcomes of this Institution that these sort of novelties were becoming more and more discussed, and more and more ventilated, than they were four or five years ago.

The discussion was adjourned till Monday, December 19th.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887-88.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, DECEMBER 19TH, 1887.

WILLIAM THEODORE DOXFORD, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Newcastle-upon-Tyne, on December 7th, which were approved by the members present, and signed by the President.

The adjourned discussion on Mr. Wailes's paper "On Improvements in the Construction of Large Stern-Frames, Rudders, and Keels," was then resumed; after which the Secretary read a paper "On the Compound Steam Turbine and its Theory, as applied to the Working of Dynamo-Electric Machines," by the Hon. C. A. Parsons.

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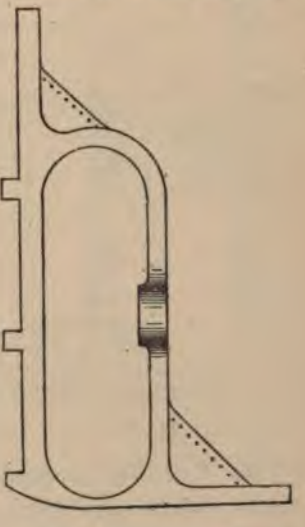
ADJOURNED DISCUSSION ON IMPROVEMENTS IN THE CONSTRUCTION OF LARGE STERN-FRAMES, RUDDERS, AND KEELS.

Mr. H. Fownes said, he had great pleasure in rising to resume the discussion on Mr. Wailes's paper, being as it was a thoroughly practical question. For many reasons he was quite in favour of this idea of manufacturing stern-frames, though not exactly for some of the reasons which Mr. Wailes stated. First, with reference to the welds, he might say that he considered this evil now entirely cured, and when the welds were made under a hammer as now required by Lloyd's, in some cases they were more to be relied upon than the other parts of the forging. He quite agreed with Mr. Wailes that one great evil of the heavy forgings was their great weight, and he considered that this evil was intensified rather in using solid cast steel stern-frames, unless, of course, they could be cast in a different section of some ribbed form, by which they could be made lighter. The connection of the stern-frame to the hull of the ship longitudinally was a matter which was entitled, he thought, to more consideration than it received, and cast steel stern-frames had this advantage that webs could be cast on them to improve this connection. (See sketch A.)

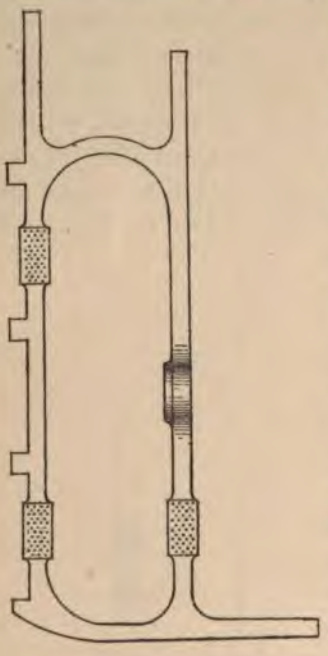


A

Referring to the great weight which was now carried aft by some of the larger steamers, he might say that he had recently through his hands a design for a rudder with a head 16½ inches diameter, weighing, with plates, probably 20 tons at the very least. The after weight in this case would probably be about 100 tons. Another form of built stern-frame, by using channel irons back to back, and somewhat similar to Mr. Wailes's, had, he believed, been recently patented; and if the riveting could be relied upon, in view of the great vibration, he was really inclined to favour the idea, chiefly on account of its greater lightness, and the better chance there was of properly connecting it to the main structure of the ship. In the event of touching the ground aft and requiring a slight repair, so as to avoid the great expense of taking out

the stern-frame, this could be provided for in even forged iron frames, by scarphing them in the manner shown in the sketch B, some of which style he recently had through his hands.

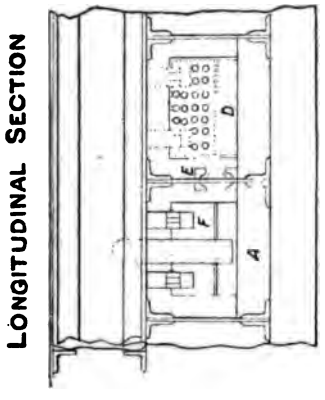
With reference to rudders more particularly, unless Mr. Wailes's rudder was any cheaper, he considered the now coming style of single plate rudder the most effective, when the plate was in the centre and the stays on alternate sides, so that the rivet had only to go through two thicknesses of iron. In regard to Mr. Stephens's remarks that the pintles often required bushing, this was surely easily got over by using loose pintles, which could be renewed whenever required. He considered, for several reasons, that Mr. Wailes's keel was to be commended. It cut two ways; he gained greater displacement, and by getting rid of the bilge water, had less weight to be carried; but he feared that its cost would stand against its general adoption; and if forged keel bars were entirely dispensed with in favour of Mr. Wailes's keel, as a forge master he should consider Mr. Wailes a benefactor to the species, by getting rid of a most unprofitable manufacture.

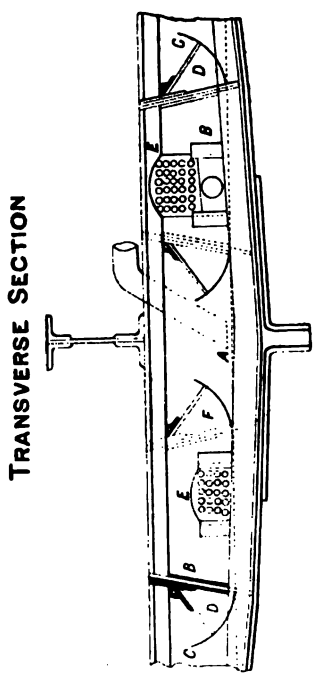


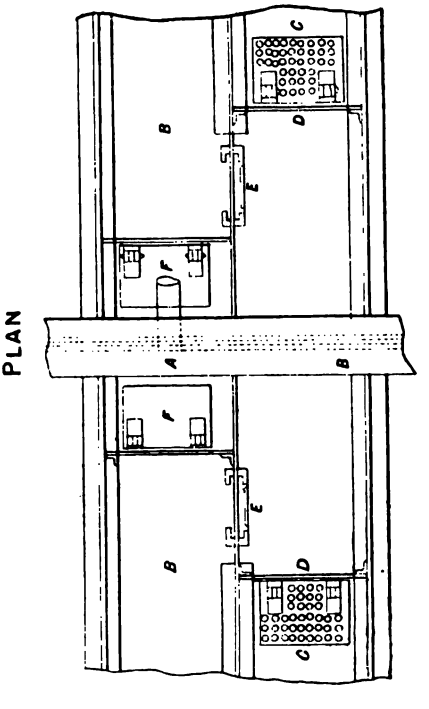
B

Mr. B. G. NICHOL considered the paper one which mostly concerned the shipbuilder and forge master. He (Mr. Nichol), therefore, had some diffidence in making remarks on the subject of the paper. There was, however, one point raised during the discussion which deserved some amount of attention from the engineers. That was the getting rid absolutely of bilge water, and the evil effects consequent upon considerable quantities of bilge water remaining in vessels, and it was mainly upon this point that he proposed to make a few observations. Whether the channel keel, as proposed by Mr. Wailes, would greatly facilitate the removal of the bilge water he was not prepared to say, but he felt sure that dirt would flow into the channel keel along with the water, unless effective and easily accessible strums were provided. One of the engineering members of the Institution—Mr. Stephenson, of Wallsend—

had done something in this way by devising a very simple and effective arrangement which could be applied to any existing ships, and which, as







experience had proved, enabled the whole of the bilge water to be got rid of. (Mr. Nichol directed attention to a model of this arrangement, a sketch of which is here given, and explained its action in a clear

and lucid manner.) The apparatus occupies two frame spaces at the after-end of the engine room, or in any of the holds, and consists of a set of four nearly vertical hanging valves. The two in the forward frame space being perforated and so arranged that when the vessel rolls they open outwards, towards the sides of the vessel, thus allowing dirt, ashes, or small coal, etc., to be washed into the wings, where it is retained by the hanging doors automatically closing on the return roll, and from whence it may be readily removed. The bilge water, which passes freely through the perforated doors, then flows through the ordinary limber holes into the after frame space, in which are fitted, at some distance apart, two solid hanging doors arranged to open as the vessel rolls, towards the *centre* of the vessel, thus forming a water trap in which water rises higher and higher with each successive roll of the ship, and thus the suction pipes fitted in this space are provided with a continuous supply of water so long as any remains in the vessel. Of course this chamber, being in the centre of the ship, the bilges are cleared of water when in dock, or on an even keel just as with the usual arrangement. The chief merits of this appliance are that it acts automatically, that the hinged perforated doors may be lifted out, cleaned, and replaced readily, and that the cost of application is very small. He thought the members could not fail to be interested in the novel structures Mr. Wailes had brought before them. One of the questions asked was, whether the form of stern-frame and keel, advocated by the author of the paper, were equally strong as those generally used, and he had made a few calculations to ascertain this, based on the dimensions Mr. Wailes recommended for two similar ships. Taking a length of 6 feet, or about the distance between the boss and the keel, he found that Mr. Wailes's I section stern-post would bear a transverse or athwartship strain of 102 tons, while one of the ordinary type would give way with a strain of 37 tons 16 cwt. In the fore and aft direction, in which there was little or no strain, the ordinary form had the advantage, as it would bear 60 tons 9 cwt. as against 39 tons 14 cwt. on Mr. Wailes's plan. Taking the keel in the same manner, and taking the same length, the channel keel would bear a vertical strain of 63 tons 7 cwt. and a transverse load of about 70 tons, as against 10 tons 12 cwt. and 8 tons 5 cwt. for the ordinary form. The part to which he attached most importance, and where the greatest difficulty presented itself, was the scarphing of the stern-post to the boss. An examination of the illustrations showed, however, that this point had been well considered, and a good mechanical arrangement contrived. The centre web of the I section was, throughout the length of the

scarph, carried in a slightly diagonal direction, without diminution of thickness, and a projection formed on the centre web for each of the ends of the scarph to abut against. The plating of the vessel was arranged to properly cover the outside flanges of the I section, and covering plates could readily be fitted inside. Of course, in adopting the form advocated by the author, the cost would have to be reckoned with; but, so far as strength was concerned, and the certainty of sound workmanship being secured, the structures put before them by Mr. Wailes would be equal, if not superior, to anything in existence.

Mr. JAMES H. LAIDMAN, on the invitation of the President, said, he was much obliged for the sanction of the meeting giving him (being to some extent an interested party) an opportunity of stating his views on this question. The origin of his thinking about the question was to be found in the fact of his having had considerable experience in dealing with broken stern-posts. During the last five or six years he had superintended the removal and repairs of several of various sizes, and probably this had led him, as one occupying a position in connection with shipbuilding, to consider whether something could not be done to remedy or mitigate the existing defects of the present form of stern-posts. No doubt one great drawback was a want of uniformity in construction in comparison with the stern shell plating of the vessel to which it was attached, and also a superabundance of overhanging weight at the extreme after-end of a vessel, which naturally tended to cause excessive vibration when the propeller was in motion. He therefore thought that part of a vessel might be more advantageously constructed by the adoption of a combination of girder, sectional bars, forgings, or steel castings. Messrs. Earle's Shipbuilding Co., Hull, in whose employ he was, had made several cast steel stern-posts, the idea being first originated in their establishment by the late Mr. Cameron, formerly superintendent engineer to Messrs. Wilson, Sons, & Co., of Hull, his object being, by this substitution, to lessen the liability to damage; his firm having had no less than four vessels with broken stern-frames within a very short period. He (Mr. Laidman) had noticed that the breakage or fracture invariably occurred behind the inner post at the bottom of the aperture, and on the outer post near to the top of the aperture. He took it from his own experience of what he had observed of these breakages and fractures, and from the conversations he had had with the captains and engineers of these vessels. But whether these fractures were brought about by the action of the sea, or solely when vessels touched the ground, he was not at present going to dispute. But allowing that these stern-posts were broken

by the action of the sea, he ventured to assert, although his theory might not meet the views of everyone, that the reason the fractures occurred in these particular places was that the rudder acted as a back stay to the outer post, evidenced by the fact that rarely, if ever, have stern-posts broken midway on the outer post. The rudder having such a large surface area in comparison with the stern-post, it consequently receives the greatest strain from the action of the sea, and being effectively secured by its pintles to the gudgeons of the stern-post, it carries the latter with it whenever it yields to an extraordinary amount of stress, breaking it at the fore part of the aperture, the enlarged portion at the bottom of the inner post acting as a fulcrum. If the force of the blow is not then expended, it generally extends in a triangular direction, twisting the heel of the post either to starboard or port, as the case may be, breaking the outer post near the top of the aperture, and often continuing on until it breaks the rudder at the junction of the rudder post with the main body. (In connection with this, he, Mr. Laidman, quoted a case of one of Messrs. Wilson's vessels having had the stern-post broken twice almost exactly in the same place.) The question naturally arose, why was it requisite to have so much length of solid material to form the outer post when experience proved the rudder to be strong enough to keep the back post rigid? He had noticed repeatedly that the gudgeons of the stern-posts of vessels being repaired at their establishment were worn to a considerable extent through the action of the pintles and by being continually re-bushed; so much so that he could enumerate cases where a 10 in. by 6 in. post had gudgeons with only 1¼ in. outer surface left to surround the pintles. If this was sufficient, what necessity was there for such a massive substance to which to attach the gudgeon? These discrepancies could be overcome by the adoption of the H section stern-frame, where the gudgeons are fitted between the outer flanges and the boss, (which was shown on his plan also as a separate piece,) with two vertical forks above and below the boss ring, within which the double channel, or H section bars, are fitted and kneed on to the boss tube. He admitted there was riveting required, but why should it be objectionable when it could be made reliable? They had built several twin screw vessels, the propeller crutches, or A frames, of which were simply secured to the shell plating and the keel with rivets through the palms of the crutches, usually about twenty rivets serving the purpose for each palm. There were some very large twin screw vessels running at the present time—the "Hill" Line for instance—with the crutches secured as described, and which answered their requirements. If, then, the rivets prove their efficiency in this case,

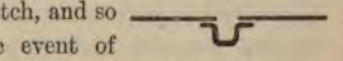
there would be no difficulty in effectually securing the boss tube to the H section stern-frame, more especially as the style in which they are fitted together relieves the strain upon the rivets. The most important part, however, was the sole piece, which he considered should by all means be retained. Whatever alterations were made in the superstructure, he would still hold to the original idea so far as the sole piece was concerned, and likewise swell it out more horizontally between the posts to give greater strength to it. Regarding this point, he might state that on the American lakes at present they were using balance rudders, dispensing with the outer post entirely, and the sole piece forming a base for the rudder keel. These were being fitted in vessels 260 feet long, and had been proved to be a success on the lakes, where they experienced exceptionally heavy weather at times. If this answered, he did not see, therefore, why a substantial sole piece connected to an H section stern-frame ought not to prove a satisfactory combination. He thought he had said as much as was requisite on the subject, and begged to thank them (not being a member of this Institution) for the attention they had given him.*

Mr. H. Macoll said, owing to the train being late he had unfortunately lost the previous portion of the evening's proceedings, and was somewhat at a loss to know what had been done. In looking at the proposed stern-frame the first impression, considering the matter from the repairing point of view, was a tendency to find more faults than benefits. First, as to the cost and, more specially, the time occupied by repairs. Supposing a broken stern-frame which was a steel casting: the time occupied making a pattern, then getting the required portion of the frame cast, annealed, tested, etc., and brought to the dock or slip, would go into more time than most shipowners would afford or the underwriters care to pay for. With a medium-sized vessel, a solid forged stern-frame could be repaired and the vessel undocked well within two weeks. It is certain a very much longer time would be taken up repairing the steel casting. In the case of the H section, he would be afraid to say how long they might have to wait before the rolls were put in for the small quantity of material that would be required. From these considerations, so far as he could judge, any saving arising from less first cost and saving in weight would be a good deal discounted in effecting repairs. Generally he had an impression, in the event of a vessel bumping on the ground aft, it was of little moment what style of post was adopted; when the weight of the vessel and consequent momentum was considered, it was

* Mr. Laidman showed a sectional drawing illustrative of his remarks.

pretty certain the post would come to wreck, while there was a further probability, in the event of the vessel grounding heavily with the new style of post, that there would be more straining and distortion extending over a greater area than with the ordinary forging. With regard to repairing, it might be said that a spare piece might be carried on board. That was quite true; but it was usually the unexpected that happened, and it would likely be found in most cases that the post would be fractured in a way regardless of the arrangement of scarphs and so render the spare piece useless. Again, the larger cross section of the proposed stern-frame would somewhat interfere with the propeller efficiency by causing a large eddy or backwash, and the rudder was open to the same objection but not so strongly. With respect to the riveting in the H frame, it seemed uncommonly close to the heel or root, and it would be difficult to make sound work with the rivets placed so close to the heel. He would be pleased to have explained how the better attachment to the transom floor was made. In the ordinary post the transom floor was placed close up to it and secured by two angles riveted through the post and floor. In the plan of the new post shown the transom floor was placed a considerable distance before the post, and he did not see where the better attachment came in. Then he was doubtful, considering the flexibility of steel, whether there would not be considerable vibration and a tendency to wear the rudder pintles; in fact he was inclined to think there would be considerable vibration in the whole structure. He had not the slightest intention to contend that the present style of stern-frames was anything like satisfactory, very few who had to do with them would admit that; still he could not help remarking if scarphs were admissible in built up frames and also in cast steel frames, there was no good or sufficient reason for insisting on solid forgings being in one piece when made of iron, by scarphing the ordinary post; the most difficult part of the whole operation, that is, the closing up welds, would be avoided, and the strength could be easily made up by increasing the section in the way of the scarphs. And in regard to the ordinary rudder, he had found by widening the bow and double riveting the plating down the after side that the riveting remained perfectly tight. As to the hollow keel, no doubt it was of great importance to get the bilge water disposed of, and the form of keel shown was well adapted for that purpose; still, considering the great tear and wear of the lower portion of the keel aft by vessels getting close to the ground, in most trading and coasting vessels, some steamers in a few years having ground something like 1½ inches off the lower part of the keel, it would be necessary to increase the thickness

of the proposed keel considerably to allow for this waste, in order to prevent the keel wearing through and thus involving serious consequences. Might he also suggest the upper part of the keel being flanged over to take the garboard strake, as shown in sketch, and so avoid bending these plates, and in the event of damage, the keel would be unshipped easier. Although in this case the scarphs of the keel would be more difficult to fit, yet it might be got over. With vessels trading to shallow harbours and muddy rivers, the Thames for instance, it would be found that the trough would silt up soon, and should be more frequently looked to than was the custom with most ballast tank vessels, as in his experience it was quite a common thing to find a deposit of several inches thick over most of the flat of bottom under the tank tops. However, although for the reasons given it was not clear to him that the propositions set forth by Mr. Wailes were beneficial in all respects, in fact very few improvements in ships were, yet he had placed before them the elements of a most important improvement, and a considerable step in the right direction.



Mr. Thos. McNabb said, he understood that some objection had been taken to the form of keel advocated by the writer of the paper, on the part of superintendents or those who should know something about the construction of vessels, principally on the ground that it would be difficult to rivet the garboard strake to it. For his part he could not see that there would be any more difficulty to rivet the shell plating to this keel than there would be in ordinary cases, and it had the merit, as he saw it, of requiring shorter rivets. So far as the difficulty that he had alluded to was concerned, it was suggested to him that the room for riveting was limited. Well, so was it in the ordinary cases of riveting, the aft plating to the stern-frames or the stem plating to the foremost frames, left little room for riveting there, and he did not see it would be much more difficult in riveting the shell plating to the sides of this keel than there would be in either of the cases he had referred to. There was one point, he thought, of particular importance to the shipowner, and that was the desirability of obviating as far as possible the carrying of any unnecessary or unprofitable weight in the vessel. As he understood it, Mr. Wailes's plan would do away with the carrying of such weight, that was the water, and a portion of the cement, in which case he, thought, a great point would be gained. In that sense and that direction, he thought, that Mr. Wailes's plan was not only a good one but one that it was desirable should be studied and adopted, if possible, if not in its entirety, in some modified form, although he for his part did

not say a modification was required. With regard to the water that was usually carried, all who had anything to do with the management of steamers, knew that they carried a much larger quantity of water than they ought to do, it being impossible in fact to remove the whole of it. A remark had been made by one of the gentlemen who had spoken, about the probability of this channel being choked by mud that accumulates. He had been very often in bilges and tanks, and knew from experience that a great deal of filth and dirt was to be found in the bilges of vessels. But in this case he thought it would be a very simple matter, when out of dirty water, and in the open sea, the clear ocean, to flush these channel courses as they did the drains and sewers of towns; because as a rule it was only mud, and would be carried through the strums without any difficulty. Referring to the stern-post, he was not entirely at one with Mr. Wailes in his object in improving the character of the stern-post. He had seen and had to do with the repairs of a good many stern-posts, and he had often thought that something might be done to improve, he did not say the quality of the posts themselves, but to simplify the repairs where fractured at any part; a weld is always a weak point. Mr. Laidman stated that which was a fact known to all who had anything to do with the repairs of vessels, that stern-post usually gave way just at the weld abaft the forward or main post, or between the two posts on the keel, and if a second fracture, some distance below the trunks on the after-post usually where the welds are. If stern-posts were made in sections and as suggested by Mr. Wailes, it would be a simpler matter to remove the plating from the lower part, than to remove the stern-post altogether by breaking the scarph below the boss and thus remove it without having to disturb the whole after part of the vessel and take out the stern-frame. A little while ago he had to do with a vessel at Stockholm, which had the frame broken between the posts, and in order to repair it they had to remove the whole affair at a very considerable cost of money and time, and therefore as a matter of economy in repairing, the subject was worthy of consideration by both owners and underwriters. That was a question he knew shipbuilders and engineers did not study very much, but those who had to do with the repair of ships did sometimes think something could be done to obviate this special difficulty with stern-posts. It was a most desirable object, and one that ought to have a great deal of attention given to it: it was not impossible, he hoped, notwithstanding what Mr. Laidman had said. He (Mr. McNabb) quite appreciated the point he Mr. Laidman had made of the leverage brought to bear upon the stern-post by the rudder, and he believed that the posts usually gave

way, from the cause suggested by him; but he held, it was absolutely impossible to prevent a stern-post breaking in given circumstances, say, striking the ground heavily. It was desirable, however, that when the stern-post did break, some means should be discovered or adopted by which it became unnecessary to remove the whole structure. He referred to what had occurred in his own experience, when on several occasions they had to take out the whole stern, when they should only have had to take out the lower part if it had been constructed in sections. He thought Mr. Wailes had proposed a plan worthy of the consideration of practical men, whether the channel keel be adopted or not. He saw no difficulty but many advantages in connection with it. His experience told him that a vessel of ordinary size, carried forty or fifty tons of cement to fill in bottom work, and cover the rivet heads. If a half or a third of the quantity could be made sufficient then so much was gained, besides the quantity of water that was not required to be carried. According to present arrangements they could not, in fact it was impossible, as ships were at present constructed, to drain all the water out of a vessel. Mr. Macoll referred to corrosion—there was not much in that; it would take a very long time indeed for corrosion to materially affect the channel keel as suggested by Mr. Macoll.

Mr. WAILES regretted that the limited time at the disposal of the meeting had rendered it impossible for the discussion to be carried on to the end, consequently the duty devolved upon him to explain important points that could have been more ably elucidated by members of the Institution. He begged to thank Mr. B. G. Nichol for the excellent manner in which he explained the relative strains and strengths of the various sections, which he had much pleasure in endorsing. They proved conclusively the cast steel girder frames to be double the strength of the forged frames, and this strength was maintained with 25 per cent. reduction in the weight of material, which in this, a comparatively small vessel, amounted to about two tons. He would not advocate any further reduction in the weight, because he thought double their present strength was little enough to attain the desired efficiency.

Mr. Arnison's allusion to massive riveting was very true. The rivets in a solid frame would be $10\frac{1}{2}$ inches long and $3\frac{1}{2}$ lbs. in weight, and would, of necessity, be riveted by hand. The rivets in a girder frame would be 3 inches long and 10 ozs. in weight, with the advantage of being riveted by machinery as well as by hand, also three-fifths of the drilling would be saved. The wooden moulds would also be lighter and cheaper than usual, possibly more labour would be expended in the process of

moulding, but there were many advantages facilitating easy construction, therefore they should be made at about the same cost as the forged or solid cast frame.

He could not believe Mr. Macoll was in earnest in stating that he would remove the whole frame and fittings in preference to casting a new bottom girder piece. The members of this Institution were in a position to judge which method would incur the least cost or detention. Mr. Boyd very aptly put this question in a nutshell when he said it seemed to him unpractical and unreasonable the amount of work to be performed to a broken stern-post when the cause was only a crack at the heel. Mr. Macoll had not recognised the fact that the stern-frame was fastened to all the transom frames with an intercostal plate riveted to its vertical flanges. It was also fastened with knee plates to the upper and under side of the peak top-plating, and secured with gusset plates to the ribs and keelsons. The foot of the ribs was riveted to the vertical flange, the frame being tied throughout to the main structure so as to support its own weight *before* the shell plating was attached.

Mr. Thompson did not like the shape, as shown on Fig. 1, Plate VI., nor the existence of tuck plates. All he could say in reply was, the same efficiency could be attained in any other shape that might be found necessary.

With regard to Mr. Stephens's suggestion, a rudder could be easily fitted between the after flanges of the post and worked as he described, without pintles, etc. For this purpose the rudder main piece would be formed of a semi-cast steel tube, etc.

Mr. Fownes said the rudder should be made with web flanges and stays, so as to take single plating. By referring to Fig. 1, Plate VI., it would be seen that the cast steel rudder was made identically in the way which he had proposed. It was very gratifying to hear from him that welds were now perfect, but in his (Mr. Wailes's) opinion this did not constitute an efficient frame in conjunction with ordinary weight and bulk.

He was indebted to Mr. Laidman for the valuable information he had afforded to the discussion on the paper in describing his experience and the nature of defects that had come under his notice. His remarks were most interesting. He agreed in a measure with his proposals for remedying the defects, viz., by the substitution of channel or girder for solid section, which, certainly, was an advance in the right direction. At the same time Mr. Laidman did not, in his opinion, go far enough ; because he (Mr. Wailes) was convinced that the greatest efficiency could not be attained unless the forged or cast solid section was eliminated throughout the frames, as shown on Fig. 1, Plate VI.

He would make no further reference to the proposed improvements, except that he might remark the time should not be far distant when heavy deadwood frames might become relics of the past. Twenty-five years ago the hulls of iron ships were built much heavier; now, they were not only lighter but very much stronger, entirely due to a proper distribution of material. This principle, applied to frames referred to in the paper, would give beneficial and lasting results, effecting an immense saving to underwriters and insurance companies, and minimising the loss of valuable lives at sea.

With reference to *Keels*, he wished it to be understood that he did not pretend to the origin of the channel, but to the construction of a keel of this description that could be practically introduced into ships of large as well as of small tonnage. He might say it was entirely due to recent improvements in the manufacture of steel that he had been enabled to place this subject before them. The strains given by Mr. Nichol showed that this structure had a breaking strain of more than double that of an ordinary bar keel. In weight it was 25 per cent. heavier, but its extra displacement more than counterbalanced this. The cost of drilling was less than usual, the riveting much lighter, and it could, as Mr. Tweddell said, be done best by machine. There was no more fear of the flanges shearing the floors than in an ordinary bar keel. It would not be practicable, as had been suggested, to make the flanges of the keel form the garboard strakes.

The full-sized model clearly showed the simplicity and efficiency of the scarphs. Mr. Macoll had remarked that this keel in small vessels accustomed to take the ground would soon wear away. He did not agree with this view, because a bar keel would be destroyed when worn down to the rivet, which would not be more than an inch. Now, the bottom of the channel keel, being thicker than an inch, would not be so soon destroyed; and again, if need be, it could be easily repaired, with outside straps. The channel keel was best suited to vessels with double bottoms of the usual type; for cellular bottoms, some modification of the centre keelson would be required.

Mr. Thompson desired to know the estimated saving in the first cost compared with patent cement. This would be £300, as against £450 for Portland cement. Mr. Stephens appeared to think that if the vessel took a permanent list the water could not find its way into the channel. He was certain it would be a difficult matter to keep it out under any conditions; and it must be remembered that there are all the usual bilge suctions as well as the central one. Of course, dirt and other matter would naturally fall

into the keel, thereby removing the elements that endangered the bottom while washing about. This matter could be easily removed when the bottom was pumped dry; and, as Mr. McNabb said, when at sea the channel could be easily sluiced out by the introduction of clean water, there being a clear run fore and aft. This could not be done under present conditions, because of the transverse floorings.

Mr. Arnison's proposal of making the scuppers underneath the frames would not admit of the bottom being pumped dry, because the suction pipe would be above the bottom. As he said before, the suction pipe must be below the level of the bottom to effect this purpose. It will also be observed that this pipe is effectually protected by suitable guards. In addition the vessel would have all the usual limber holes.

Mr. Nichol's model for the removal of bilge water had many advantages, but its virtues were lost when it is recognised that the bilge water cannot be removed until after the vessel has gone to sea; whereas his object was to do this before she left her loading berth, so that the *cargo* might be substituted for the ejected bilge water. The weight of the marine engine had been reduced 25 lbs. per indicated horse-power during the last seven years, which was equal to about 12 tons. Efforts were still being made for further reduction, with a view to increasing the dead-weight carrying capacity; this improvement is working slowly, whereas, by the introduction of the channel keel, an immense saving of weight would be effected at once, a boon to shipowners, and an element of danger removed.

In conclusion he had to thank the members for the interest and consideration they had given his paper.

The PRESIDENT said, he did not think they could do less than pass a vote of thanks to Mr. Wailes for his able paper. One great advantage of such a paper as this was that it took them out of the ordinary rut they were apt to run in. They had always had solid stern-posts and keels, and were apt to think that nothing could be better, but now there was an evident tendency in favour of some improvement in the construction, more especially of stern-frames, and he did not himself see why something in the direction proposed in the paper should not be carried out. With regard to the getting out of the bilge water, he did not think there could be anything difficult about it. It was easy getting it out of a sailing ship's channel, not so deep as the one proposed, and he had never heard of it getting choked up with dirt. He proposed that they should pass a vote of thanks to Mr. Wailes.

The vote of thanks was carried by acclamation.

THE COMPOUND STEAM TURBINE AND ITS THEORY, AS APPLIED TO THE WORKING OF DYNAMO-ELECTRIC MACHINES.

By the Hon. C. A. PARSONS.

[Read before the Institution on Monday, December 19th, 1887.]

We shall begin by describing water turbines and some of their performances, together with the necessary conditions for economy in motors of this class. We shall then describe the compound steam turbine, and draw a parallel between it and the water turbine, showing by the help of the latter that the conditions for high economy are fulfilled in the compound steam turbine. We shall then give figures to show what the theoretical economy of the compound steam turbine should be, and then deal with the dynamo and its combination with the steam turbine.

Water turbines have been for many years in extensive use in Europe and America, and have, after many experiments, been brought to a very high degree of perfection, as is shown by the numerous tests that have been made to ascertain their actual efficiency.

Perhaps the most carefully arranged and the most exhaustive of these experiments are those made by Mr. James B. Francis on the Tremont turbine at Lowell, Massachussets. The result showed that the horse-power indicated on the dynamometer attached to the shaft amounted in some cases to 79·3 per cent. of the total power of the water, whilst those made on another turbine of still more improved design gave an efficiency of 88 per cent.

The theory of the turbine has been thoroughly dealt with and understood, and theoretical reasoning leads also to the conclusion that such a high efficiency in a turbine is quite possible provided that certain rules are adhered to in the design, and provided also that certain essential conditions as to the flow of water are provided for. All water turbines consist essentially of a set of fixed vanes, called guide blades, and a set of moving vanes called the wheel; the former guide the water towards the direction of motion of the latter. The important

conditions for economical working being that the shape of the blades and the velocity of the wheel shall be so arranged that there shall be no shock or sudden change of the velocity of the water in passing from the guide blades to the moving blades, and also that as the velocity or energy of the water on leaving the wheel is lost it shall be reduced to the utmost extent by the formation of the blades.

This leads us to enquire what has been found to be the best velocity of wheel to meet these conditions.

In Mr. J. B. Francis' experiments, p. 33, we find—

Experiment	42.	Velocity of wheel	30	per cent.	velocity due to head.	Efficiency	67.
„	41.	„	39	„	„	„	72.
„	36.	„	50	„	„	„	78.
„	30.	„	63	„	„	„	79·3.

We have here then the speed which gives the maximum efficiency and a measure of the diminution of efficiency corresponding to a reduced speed.

The essential conditions for high efficiency are, as we have said, absence of shock and low residual velocity. These conditions, in the case of the water turbine, can be better obtained in the types called the outward or inward flow than in the parallel flow, for the large volume of water to be dealt with necessitates long blades of double curvature for the last mentioned type, these are objectionable, while it is more difficult to minimise the residual velocity of the water leaving the wheel. Principally these reasons have led to the more general adoption of the outward or inward flow types than of the parallel flow. After careful consideration, however, the parallel flow type seemed more suitable to the compound steam turbine, and has been accordingly adopted.

Fig. 2, Plate XI., shows the arrangement of 90 complete turbines, 45 lying on each side of the central steam inlet. The guide blades R are cut on the internal periphery of brass rings, which are afterwards cut in halves and held in the top and bottom halves of the cylinder by feathers; the moving blades S are cut on the periphery of brass rings, which are afterwards threaded and feathered on to the steel shaft, and retained there by the end rings which form nuts screwed on to the spindle. The whole of this spindle with its rings rotate together in bearings, shown in enlarged section, Fig. 3, Plate XI. Steam entering at the pipe O flows all round the spindle and passes along right and left, first through the guide blades R, by which it is thrown on to the moving blades S, then back on to the next guide blades, and so on through the whole series on each hand, and escapes by the passages P at each end of the cylinder con-

nected to the exhaust pipe at the back of cylinder. The bearings, Fig. 3, consist of a brass bush, on which is threaded an arrangement of washers, each successive washer alternately fitting to the bush, and the block, while being alternately $\frac{1}{32}$nd smaller than the block outside, and $\frac{1}{32}$nd larger than the bush in the hole. One broad washer at the end holds the bearings central. These washers are pressed together by a spiral spring N and nut, and, by friction against each other, steady or damp any vibration in the spindle that may be set up by want of balance or other cause at the high rate of speed that is necessary for economical working.

The bearings are oiled by a small screw propeller I attached to the shaft. The oil in the drain pipes D and F, and the oil tank D lies at a lower level than the screw, but the suction of the fan K raises it up into the stand pipe H over and around the screw, which grips it and circulates it along the pipes to the bearings. The course of the oil is as follows:—The oil is forced by the propeller I and oils the bearing A, the greater part passes along the pipe E to the end bearing C, some after oiling the bearing C, drains back by the pipe F to the reservoir D, the remaining oil passes along through the armature spindle, oils the bearings B, and drains into the reservoir D, from which the oil is again drawn along the pipe G into the stand pipe H by the suction of the fan K. The suction of the fan is also connected to the diaphragm L, and forms, with it and the spring M, the principal part of the governor which actuates the throttle valve V. Fig. 4, Plate XII., is the electrical control governor, which will be further described in connection with the dynamo. It acts directly upon the controlling diaphragm L by admitting or closing a large access of air to it, and thus exercises a controlling influence upon it.

For small differences of pressure the velocity of air or steam passing through orifices or short tubes is given by the same formula as that for water. The heads of pressure have to be calculated in each case in terms of the respective fluids, and for small differences of pressure the velocity of efflux is the same for the same head in all cases. This has been recognised as a fundamental principle; it has also been verified in some of the cases we are going to consider by actual measurements.

We now proceed to consider the action and condition of the steam as it passes through the successive turbines, but, before doing so, it will be necessary to go into some calculation in order to form a correct basis to start from.

The velocity of efflux of steam flowing from a vessel at 15·6 lbs. per square inch absolute pressure through an orifice into one at 15 lbs.

absolute pressure is 366 feet per second. The drop of pressure of ·6 lbs. corresponding to a diminution of volume of 4 per cent. in the opposite direction. We must now suppose that the turbines are so proportioned and the blades so diminished in size that each one nearer the steam inlet O has 4 per cent. less blade area or capacity than the preceding one all the way from each of the exhaust ends up to the centre.

If we work this out we find that after 45 turbines the pressure will be about 69 lbs. above the atmosphere at the inlet. The steam will have followed some curve of temperature and volume very near the adiabatic but on the isothermal side of it, the velocity of flow will be slightly greater near the inlet in consequence of the increased temperature. The steam enters from the steam-pipe at 69 lbs. pressure, it passes through the first turbine, consisting of a ring of guide blades and then a ring of moving blades, and falls 2·65 lbs. in pressure, the velocity due to this fall in pressure is 386 feet per second, its volume increases by 3·85 per cent. of its original volume, it passes the second turbine, falls 2·55 lbs., and again increases its volume in the same ratio, and so on till it reaches the last turbine, where its pressure is 15·6 lbs. before entering and 15·0 lbs. on leaving it to flow into the exhaust pipe. The velocity due to the last drop is 366 feet per second. The steam has, therefore, nearly the same velocity of flow for all the turbines; in other words, the error in assuming the velocity due to the head to be 376 feet per second throughout does not exceed 3 per cent. The velocity of the wheels at 9,200 revolutions per minute is 150 feet per second, or 39·9 per cent., the mean velocity due to the head throughout the turbines.

On comparing this ratio of velocity of wheel to velocity of flow with that of the Tremont water turbine we find a corresponding efficiency of a little over 72 per cent. Hence in the compound turbine we are describing, the velocity of the blades is sufficient to secure a very high return of useful effect. We may, therefore, assume that if the blades be equally well-shaped in the steam turbine as in the water turbine, and that the clearances be kept small and the steam be dry, then each turbine of the set will give an efficiency of at least 72·5 per cent. We say, "at least," because as each turbine discharges without check into the next, the residual energy after leaving the moving blades is not lost as it is in the case of the water turbine we are considering (it amounts to from 3 to 5 per cent. of the energy), but continues into the next guide blades, and is wholly utilised there in assisting the flow. This unchecked flow from one turbine to another is a great advantage of the parallel flow type over other types where a number of turbines are compounded. It also mini-

mises the skin friction, as nearly the whole of the moving part is covered with blades, and there is consequently no appreciable loss due to this cause.

As each turbine of the set gives 72·5 per cent. efficiency, it follows that as the steam at all points expands gradually without shock that the motor as a whole will give an efficiency of at least 72 per cent. of the total mechanical energy of the steam, or in other words, over 72 per cent. of the power derived from using the steam in a perfect engine, without losses due to condensation, clearances, or friction, and such like. A perfect engine working with 90 lbs. boiler pressure, and exhausting into the atmosphere, would consume 20·5 lbs. of steam per hour for each horse-power; a motor giving 70 per cent. efficiency would therefore require 29·29 lbs. of steam per horse-power per hour.

We have now gone sufficiently into the question to show clearly that in the compound steam turbine we have a motor whose theoretical efficiency is very high indeed. The fact that at each turbine of the set the temperature is constant, enables us to predict that there can only be a very minute loss arising from condensation. This has been conclusively verified by experiments with superheated steam, coupled also with the fact that "for small differences of pressure gases and vapours act like liquids in flowing through orifices and tubes, in virtue of the small differences of pressure, and that the velocity of flow is regulated by the fundamental formula $v = 8\sqrt{h}$." These three facts draw the analogy between the water turbine and the compound steam turbine for efficient working as close as it is possible to draw anything, and it does not seem too much to expect, in the larger sizes at any rate, an equally good efficiency.

The dynamo which forms the other portion of the electric generator, Fig. 1, Plate XII., is coupled to the motor spindle by a square tube coupling fitted on to the square spindle ends. The armature is of the drum type, the body is built up of thin iron discs threaded on to the spindle and insulated from each other by tracing paper. This iron body is turned up and grooves milled out to receive the conducting wires. For pressures of 60 to 80 volts there are 15 convolutions of wire, or 30 grooves.

Fig. 5, Plate XII.—The wire starting at *b* is lead a quarter of a turn spirally *c* round the cylindrical portion *a*, then passing along a groove longitudinally is again lead a quarter turn spirally *d* round the cylindrical portion *a*, then through the end washer and back similarly a quarter turn over *e*, then led along the diametrically opposite groove, and lastly, a little over a quarter turn *f*, back to *g*, where it is coupled to the next convolution.

The commutator is formed of rings of sections; each section is formed of short lengths; each length is dovetailed and interlocked between conical steel rings; the whole is insulated with asbestos, and when screwed up by the end nut forms with the steel bush a compact whole. There are 15 sections in the commutator, and each coupling is connected to a section. The whole armature is bound externally from end to end with brass or pianoforte steel wire. The magnets are of soft cast-iron and of the horse-shoe type; they are shunt wound only.

On the top of the magnet-yoke is the electrical control governor, Fig. 4, Plate XII. It consists of one moving spindle on which are keyed a small soft iron bar, and also a double finger T. There is also a spiral spring X attached at one end to the spindle, and at the other to an adjustable top head and clamping nut Y.

The double finger T covers or opens a small hole in the face U, communicating by the pipe W to the diaphragm L.

The action of the magnet yoke is to attract the needle towards the poles of the magnet, while by turning the head the spiral spring X is brought into tension to resist and balance this force, and can be set and adjusted to any degree of tension. The double finger T turns with the needle, and by more or less covering the small air-inlet hole U, it regulates the access of air to the regulating diaphragm L. The second finger is for safety in case the brushes get thrown off, or the magnet circuit be broken, in which case the machine would otherwise gain a considerable increase of speed before the diaphragm would act. In these cases, however, the needle ceases to be attracted, falls back, and the safety finger closes the air-inlet hole.

There is no resistance to the free movement of this regulator. A fraction of a volt increase or decrease of potential produces a considerable movement of the finger, sufficient to govern the steam pressure, and in ordinary work it is found possible to maintain the potential within one volt of the standard at all loads within the capacity of the machine, excepting only a slight momentary variation when a large portion of the load is switched on or off.

The resistance of the armature from brush to brush is only ·0032 ohm, the resistance of the field magnets is 17·7 ohms, while the normal output of the dynamo is 200 amperes at 80 volts. This, excluding other losses, gives an efficiency of 97 per cent. The other losses are due to eddy currents throughout the armature, magnetic retardation, and bearing friction. They have been carefully measured.

By separately exciting the field magnets from another dynamo, and

observing the increased steam pressure required to maintain the speed constant, the corresponding power was afterwards calculated in watts.

The commercial efficiency of this dynamo, after allowing for all losses, is a little over 90 per cent. In the larger sizes it rises to 94 per cent.

Assuming the compound steam turbine to give a return of 70 per cent. of the total mechanical energy of the steam, and the dynamos to convert 90 per cent. of this into electrical output, this gives a resulting efficiency of 63 per cent.

As steam at 90 lbs. pressure above the atmosphere will with a perfect noncondensing engine give a horse-power for every 20·5 lbs. of steam consumed per hour, it follows that an electrical generator of 63 per cent. efficiency will consume 32·5 lbs. of steam for every electrical horse-power per hour.

Again, with steam at 150 lbs. pressure above the atmosphere, a generator of the same efficiency would consume only 22·2 lbs. of steam per electrical horse-power per hour.

The results we have so far actually obtained are a consumption of 52 lbs. per hour of steam for each electrical horse-power with a steam pressure of 90 lbs. above the atmosphere. We, however, expect shortly to obtain results more nearly coinciding with those very high economies that theory has led us to believe possible with this system. In the larger sizes, so far as we have yet gone, we have invariably found increased economy, as in them the clearances are proportionately less and it is easier to arrange the distribution of steam.

Exceptionally low steam consumption is not the only essential attribute of an electric generator, there are other considerations, in most cases of more importance; these are steadiness of the current produced, freedom from accident, and simplicity, small first cost and cost of up-keep, little attention required, smallness of size and weight for a given output, and an almost insignificant consumption of oil.

To illustrate this we will take the installation at the Phœnix Mills, Newcastle-on-Tyne, which has been running on the average of eleven hours daily for the last two years.

Out of the original 159 Edison-Swan 16 candle-power lamps 65 are still in good condition, having run 6,500 hours at about standard brightness. Now, if the lamps had only lasted 1,000 hours on the average, the cost of lamps renewed would have amounted to about double the year's cost of fuel as at present consumed.

At the Newcastle-on-Tyne Industrial Exhibition thirteen of these turbo-electric generators lighted the whole of the courts, giving a total of about 280 electrical horse-power.

During the whole run of the Exhibition the only noticeable accident which occurred to the installation was due to the blowing out of the packing in a branch steam-pipe connecting another engine to the main steam-pipe supplying the generators, but as there was no stop-valve in this branch-pipe, the engineer in charge deemed it prudent to shut off steam at the boilers, thus stopping all the generators lighting the four courts for about three-quarters of an hour; this, however, was an accident quite external to the generator, and, as it happened, external to the main steam-pipe supplying them.

We believe that there were only three occasions during the run of the Exhibition, that a small group of lamps were extinguished for the few seconds necessary to enable a spare generator to be started and switched on to them.

The seventeen generators were in two groups; had they been placed in one group the results showed that on all occasions one spare generator would have been sufficient to keep every lamp alight.

In regard to simplicity and cost of up-keep, we may say that in a 30 horse generator there is no part that three men cannot lift, and that every part is immediately accessible.

After two years' working, of ten hours daily, we have found the wear very small indeed, in some cases almost inappreciable, the blades, or vanes, show no signs whatever, of any cutting action of the steam.

The commutators in the larger generators have generally withstood this amount of wear, while in some cases where they have been carefully attended they have suffered very little wear indeed.

We have at the present time some important experiments being carried out in regard to the generators. It would, however, now be premature to foreshadow the probable results of these trials. We may, however, say that they lead us to conclude that, more especially in the larger sizes, very much increased economy will be obtained, amounting to a reduction of from 20 to 25 per cent. of the steam consumption quoted in the paper.

We may also add that we have now supplied generators giving a total output of 1,280 electrical horse-power; about two-thirds of this amount has been for ships, and one-third for land installation. This amount does not include the Newcastle Exhibition.

We have supplied generators to the English, Austrian, Italian, Spanish, Chilian, Chinese, and United States Governments.

To illustrate the Hon. C.A. Parsons' paper on "The Compound Steam Turbine and its Theory as applied to the Working of Dynamo Electric Machines."

FIG. 4.

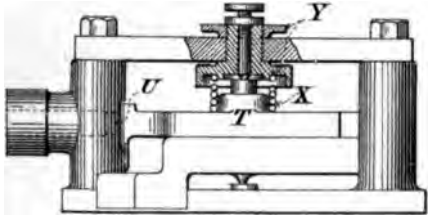
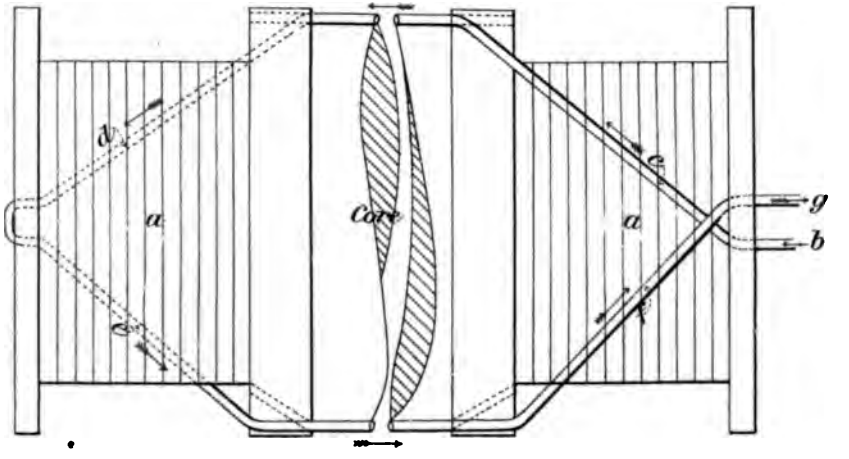
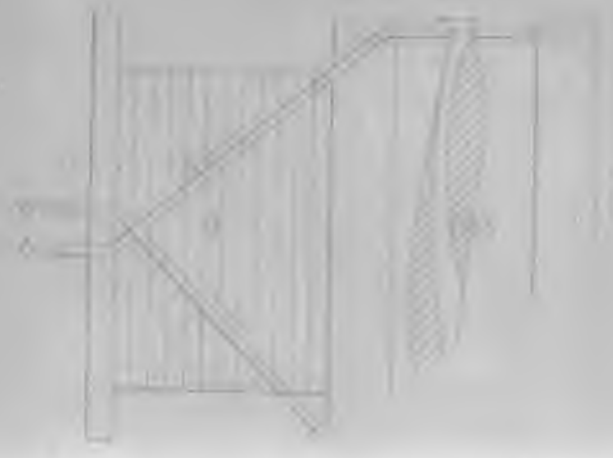


FIG. 5.





DISCUSSION.

Professor GARNETT (being invited to speak) said, he was hardly prepared to say anything on the subject that evening. He had thought that at so late an hour the discussion would probably be postponed, and he should like before saying anything to hear a few remarks from some of the members of the Institution. There were, however, two or three questions he would like to ask Mr. Parsons. The first was, on what basis he had calculated the steam consumption of a perfect engine—whether he had used Carnot's expression for the efficiency, or had calculated on the assumption of isothermal or adiabatic expansion? The second, whether hard drawn copper would not last longer than brass for the sections of the commutator? The third, whether in employing high steam pressure, such as 150 or 160 lbs. per square inch, it would be worth while, as in triple expansion engines, to employ three sets of low-pressure turbines at each end of the barrel, so as to increase the steam-way without increasing the diameter of the rotating parts? By employing three sets of low-pressure turbines, there would be no risk of leakage at the end of the barrel, as would be the case with two sets.

The discussion was adjourned till January 11th.

A Turbo-electric Generator of 3 horse-power being on view, Mr. Parsons explained more fully its construction and mode of working to the members.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887-88.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, JANUARY 11TH, 1888.

WILLIAM THEODORE DOXFORD, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting held in Newcastle-upon-Tyne, on December 19th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. H. Charlton and A. Taylor to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Douglas, John F., c/o Messrs. Wigham Richardson & Co., Low Walker.
Errington, Joseph R., c/o Mr. Bell. Contractor, Market Weighton, Yorkshire.
Holmes, John H., Portland Road, Newcastle-on-Tyne.
Reynolds, Edward, c/o Messrs. Vickers, Sons, & Co., Sheffield.
Noble, Robert, 13, Prospect Terrace, Jarrow. (Late Graduate.)
Wood, Henry A., The Longlands, Middlesbrough. (Late Graduate.)

ASSOCIATES.

Kerr, James, 7, The Retreat, Sunderland.
Metcalf, Thomas, 6, Dundas Street, Sunderland.

GRADUATE.

Donkin, Samuel, 80, Rye Hill, Newcastle-on-Tyne.

The PRESIDENT called upon Mr. R. L. Weighton to continue the adjourned discussion upon the Hon. C. A. Parsons's paper on "The Compound Steam Turbine and its Theory, as applied to the Working of Dynamo-Electric Machines."

Mr. Parsons replied to the remarks made on his paper.

Mr. William G. Spence then read his paper "On the Combustion of Coal, and some Evaporative Experiments with Natural and Forced Draught."

ADJOURNED DISCUSSION ON THE COMPOUND STEAM TURBINE AND ITS THEORY AS APPLIED TO THE WORKING OF DYNAMO-ELECTRIC MACHINES.

Mr. WEIGHTON said, he had been unexpectedly called upon to open the discussion, for he had not had the rashness to propose its adjournment at last meeting. He had hoped to have heard Professor Garnett upon the question of the expansion of the steam in this machine before saying anything himself, because that was the point, he thought, which was chiefly unsatisfactory in the paper. It would be agreed by everyone that this was a very novel machine, and that the novelty lay altogether in the motor. But so far as he had been able to understand the question, there were a great many assumptions made in the paper—there was very little that was distinctly demonstrated. He did not say that the assumptions were wrong, but they certainly were not of the nature of demonstrations. He referred more particularly to the efficiency of the machine, for that was the great point of the paper. First of all, there was the uncertainty as to its actual efficiency as compared with the water turbine. There was the further uncertainty as to the standard upon which to determine the efficiency; that was—What was unity? In a water turbine, of course, the principles which regulated its maximum efficiency were well known, and had been sufficiently demonstrated. The moving blades and the guide vanes must have certain radii given to them; that was, their shapes must be such as to derive the maximum effect from the water. That was not done, so far as he could see, in this machine for steam. The maximum amount of work which could be done by the water in the case of a water turbine was quite obvious, and was in virtue of the falling of the water from a higher to a lower level. Regarding the maximum amount of work which it was possible for the steam to do when passing through a steam turbine of the description before them—this was not by any means obvious. He did not see from Mr. Parsons's paper that this machine could in its present form attain to the efficiency which was there alleged. It might be so, theoretically. But it was not shown, for instance, that the blades and guides had the proper curvatures

to get the maximum effect out of the steam, which acted on the blades by impact. That was one point that struck him as being omitted. The difference of angle of the blades on the various wheels was not mentioned in the paper at all, he thought, and he first became aware of it by noticing it on the actual machine exhibited on the table. He presumed that was an attempt to deal with the variation in the degree of expansion of the steam as it passed through the machine. Of course the question would arise as to whether it was possible to give these blades such a curve and disposition as to realise the maximum effect inherent in the steam, when this maximum effect was compared with the maximum effect inherent in the water which acted on a water turbine. But even though it were proved that the steam motor and the water turbine were exactly analogous in their effects—even if it were demonstrated that the efficiency given in the paper (70 per cent.) was the efficiency that ought to be realised, then there arose the further question, What was the standard of perfection with which to compare it in order to rate its efficiency? The standard of perfection assumed in the paper was the case of a piston steam engine working at 90 lbs. initial pressure above the atmosphere expanding down to, and exhausting at 15 lbs. without any loss. He (Mr. Weighton) submitted this was not shown to be the true standard with which to measure such a motor; because in the motor the steam acted by impact, whereas in the piston steam engine, with which it was compared, the steam acts by expansion and not by impact. The motion here was obtained by the flow of the mass of the steam; in the piston steam engine the motion of the piston is obtained by the molecular expansion of the steam. If there were a stop cock on the exhaust of this motor, and this cock were shut and steam was admitted from the boiler into the motor, this machine would not move, he took it, because there was equilibrium everywhere and no tendency to turn. It was only when the steam got into motion (he did not mean molecular motion, but proper motion through space in one general direction) that it had any turning effect at all upon the parts of the motor. One consideration had struck him, which would seem to support the view that the two were not strictly analogous. In the steam piston engine, as they all knew, the higher the piston speed the less was the efficiency, other things being equal; in this machine the higher the speed of the vanes (other things being equal) the higher the efficiency. He thought it a great pity Mr. Parsons did not go more into those points. The analogy between this machine and the water turbine is certainly very close; but the precise grounds on which that analogy is based are not proved; they are assumed, and so also is that other point as to the

applicability to this case of the standard of perfection of the piston steam engine referred to in the paper. One matter Mr. Parsons mentioned, viz., that "the velocity of the wheels at 9,200 revolutions per minute is 150 feet per second." He should like to ask Mr. Parsons if that was the velocity that the machine referred to attained with 69 lbs. pressure of steam when it was loaded, and how much was the load?

Mr. PARSONS—That is the normal velocity of the machine when it is loaded.

Mr. WEIGHTON—Then, of course, a greater load would reduce that velocity and the efficiency of the machine would be impaired, therefore, it would always require to have that ratio between the moving force and the resistance. One consideration Mr. Parsons pointed out, which he thought very true. In speaking about the application of this motor to driving electrical machines, he said, that exceptionally low steam consumption was not the only essential attribute of an electric generator, and in so far as that was true, this was an extremely suitable machine when applied to drive dynamos.

Mr. P. MORTON (by invitation of the President) said, not having read Mr. Parsons's paper he must certainly speak at a disadvantage. In fact he was only prepared to speak upon the engine with regard to its commercial value, which was doubtless after all a most important question. He had had some experience with this engine, more particularly on board the steamer "General Havelock," which sailed regularly out of Sunderland. The motor had now been on board that steamer for about two years, and during that period it had worked continuously and satisfactorily; and, what was of very great importance in electric lighting, the lights burned with great steadiness and a remarkably small expenditure of lamps, due, no doubt, to the admirable automatic arrangement of the governors, by which the speed can be controlled and the dynamo never allowed to overrun itself and heat the lamps and destroy them; all this being done without the personal services of the attendant, no matter how many lamps were switched out and in. He was not prepared to say anything definite with regard to the exact expenditure of steam; but if they considered vessels employed in similar trades to the "General Havelock," running continuously from a coal port, and always able to purchase their coals direct from the colliery, even admitting that the expenditure of steam is a little higher than in some other engines, still, on the other hand, the general advantages which the machine offers in the minimum of attention and steadiness of light, from a commercial standpoint, probably outweighed any other disadvantage it might possess

in regard to the expenditure of steam. During the time the machine had been on board the above vessel it had always worked efficiently and satisfactorily, had given little or no trouble to the engineers, and the expenditure of lamps had been remarkably small. These were all very strong points in its favour, and pointed to its success in the employment of such vessels.

Mr. M. SANDISON said, he should just like to say, without touching upon the theory of the turbine, that to Mr. Parsons was due the credit of having been the first practically to apply the principle to steam; and he thought his motor was well up in the list of high speed engines for driving dynamos. He had had them running daily for the last two years, and he could scarcely look for an engine requiring less attention or up-keep. Pistons and top and bottom ends had gone, and the lubrication was entirely automatic. With these advantages, he thought the question of coal consumption, in this district at any rate, was of minor importance. He found the main bearings worked admirably, as far as his experience went, with the oil at a temperature of 160 degrees Fah. Of course, it was not to be expected that a departure like this at the outset should be entirely free from defects. For example, when exhausting into the condenser, the machine, as at present designed, did not gain anything in economy; they simply saved their fresh water, for the construction was such that air passed in through the ends of the steam chamber and vitiated the vacuum, if any. That, of course, was remedied by introducing a back-pressure valve in the exhaust pipe. And again, a good deal of steam was bound to pass through the unavoidable clearances round the turbines without doing any useful work. Running at this great number of revolutions, these machines must have a very decided tendency to adhere to the invariable plane, as it were; and perhaps Mr. Parsons would say if he found the gyroscopic action had any effect on the bearings in a sea-way. He (Mr. Sandison) thought this might be the greatest load that could come on the bearings. He would also like to know what was the highest pressure of steam that had been used in these motors. It seemed to him that this was more a question of unsupported length in the turbine spindle than anything else. On page 130 we found that the steam had nearly the same velocity of flow through all the turbines, and so with the same number of revolutions, we ought to get the same efficiency, no matter how many turbines were employed. In the machine illustrated we had exhausting at 15 lbs. absolute, 45 turbines on each side for an initial pressure of 69 lbs. above the atmosphere, and assuming a diminution

of pressure of 4 per cent., we should require about 20 additional turbines on each side for 150 lbs. initial pressure, the drop in the first being 6 lbs. and in the last ·6 lbs. He presumed that were this carried out the distance between the supports would be too great, and possibly two sets of turbines would be required alongside one another in a sort of compound arrangement. With reference to power developed, the dynamo quoted had an output of 16,000 watts and 21½ electrical horse-power; but he could have wished that Mr. Parsons, instead of *assuming* a 70 per cent. efficiency for the motor, had gone into a calculation of its indicated horse-power. How that was to be done he was not prepared to say. He fancied a tangential component of the mean pressure of the steam would have to be introduced, but he left that to Mr. Parsons.

Mr. A. GULSTON said, he did not pretend to be an electrician, but in regard to the dynamo end of Mr. Parsons's machine, he could say that it was only half as heavy or as large as was required in other installations to obtain the same efficiency and light. There was another point in connection with it, namely, the absolute safety of the dynamo end, for they could touch and manipulate it when the machine was running, of course, always excepting the connection with the brushes, which would be a serious thing indeed if they tried it. The tension of the electricity was also low, but its power was made up by the quantity generated, which, with the steady running of the machine, preserved the lamps. He was of opinion that all installations should be fitted with volt meters, as the overrunning of the dynamo was the almost sole cause of the destruction of lamps; also there was not nearly so much danger of short circuiting, which they knew was a very difficult and dangerous thing to deal with. They could get at the bearings and remove the armature, in Mr. Parsons's machine with much ease and adjust the commutators to a nicety. He had always found these difficulties to a very great extent obviated in this machine over others. He thought that, together with the very clever manipulation of the governor, which was practically impossible to get wrong, was all he had to say about the dynamo. No doubt others present would say something as to the generation of the currents and arrangements and winding of the magnets, as this question was one of the greatest interest to-day.

Professor GARNETT said, that there was one point in connection with the electrical portion of the generator which had escaped observation, viz. :— the advantage obtained by the very high speed of the armature. The E.M.F. of a dynamo depended on the number of turns of wire on the armature, and the speed of rotation, and, if the latter were increased,

the former could be proportionately diminished. A great many turns of wire converted the armature into a powerful magnet, which produced an injurious effect upon the field, and necessitated a change in the position of the brushes whenever any considerable change was made in the number of lamps in circuit. The very high speed of the generator enabled the armature to be constructed with very few turns of wire, so that no change was required in the brushes when the load on the machine was altered. He had been asked to say something about the expansion of steam in the turbines. It had been suggested that the steam acted by impact and not by expansion. He would call attention to the fact, that, according to the received theory of the constitution of gases and vapours, steam always acted by impact when it did work, and the only distinction to be drawn was that between the action of a stream, in which the motion of all the particles had a tendency in one direction, and the impact of the molecules when there was no such rapid motion of the steam as a whole. There was, however, no essential difference between the two actions. If a steam engine worked very slowly and without expansion, a cylinder full of steam, at full boiler pressure, was thrown away at every stroke without doing any work, and the whole of the work of the engine was done at the expense of the "latent heat" of the small quantity of steam which became condensed in the cylinder. This was clear, because, at the end of the stroke, the cylinder was full of steam at the same pressure as that in the boiler, and it must of necessity have the same temperature or it could not exist at the pressure. Hence no heat could have left this steam, and no work could have been done by it. Another extreme case was worth considering. High pressure steam might escape into vacuum through a very long narrow tube coiled up so as to occupy a small space and surrounded by a non-conductor to prevent loss of heat. In this case any heat generated by the friction of the steam in the pipe must be returned as heat to the steam, for the temperature of the pipe could not go on increasing indefinitely. The steam as it travelled along the pipe would gradually expand, without any loss of energy, as no external work was done, and the expansion involved loss of pressure and increase of velocity of the stream along the tube, which simply meant that the molecular motion of the molecules, at right angles to the axis of the tube, to which the pressure on the tube was due, was gradually transformed into motion along the tube. Precisely this kind of action took place in the injector. If the steam were received in a vessel at the end of the pipe, impact against the sides of the vessel, would reconvert the motion of the stream into motion of the molecules in all directions, and the temperature

of the steam would be found to be almost the same as at first. But if the molecules of steam impinged on a receding surface they rebounded with less velocity than that with which they struck; they did work on the surface and parted with some of their energy. This was the case when the molecules of steam struck a receding piston, and the same action took place when the steam struck the moving blades in the turbine. As the steam passed through the successive turbines its pressure diminished. Its volume and its velocity therefore increased, as in the case of the tube previously referred to, but with this difference; that whenever the steam struck the moving blades, it did work on them and parted with some of its energy, so that the steam cooled as it passed through the generator and a small portion of it became condensed. In this way the steam did its work during expansion, just as thoroughly as in the expansive working of an ordinary engine. To obtain the best effect it was necessary to vary the *pitch* of the blades in the successive turbines, so that the normal velocity of the receding blades should bear a proper relation to the velocity of the impinging steam.

Mr. J. H. Holmes said it would be a pity if gentlemen went away with the impression that this dynamo was the only dynamo which would give a low tension such as Mr. Gulston seemed to indicate, and that it was also the only dynamo which would not make short circuits. He did not think either of these statements would be correct. With regard to the design of the dynamo, he should like to ask Mr. Parsons whether he had tried, or thought of using, wrought iron in place of cast iron for the magnet? The tendency in the design of modern dynamos seemed to be entirely in the way of using wrought iron instead of cast iron. In fact he thought at first it would be better in this case; of course the very great speed at which the wires moved, as mentioned by Professor Garnett, was an important point in favour of being able to make the dynamo economical electrically. As far as he (Mr. Holmes) could see, from the size of the armature which Mr. Parsons had illustrated, he took it to be four or five inches in diameter, the speed at which the wires moved seemed to be more than three times the usual speed. 3,000 feet a minute was the usual speed reckoned upon in modern dynamos, and when Mr. Parsons's went three times that it was a very great advantage, and, of course, that was how he had so few parts in the commutator and few turns on the armature. Another point in the consideration of the dynamo was the commutator. He should like to know from Mr. Parsons whether he had tried copper for the commutator in place of phosphor bronze, or some such material which

appeared to be used. The quality and the construction of the brushes, too, whether he thought the brass wire brushes the best. The question of economy was a very important one, and he thought they should have had some exact data as to the consumption of steam per electrical horse-power. He thought Mr. Parsons mentioned 52 lbs. in his paper, he also said that he expected to increase that efficiency and had done so in some more recent experiments. He should like to hear what he had done in that way, if it involved less consumption of steam per electrical horse-power. He believed that with the ordinary high speed engine, coupled direct to the dynamo, 30 lbs. to 33 lbs. per electrical horse-power was what was guaranteed, and he believed that in actual trial one came out very considerably below that, so that in other direct driving dynamos it was possible to have a very much less consumption of steam than was the case with Mr. Parsons's apparatus at the present time. There was another point with reference to the dynamos running at the Exhibition. He did not know there were only three occasions on which the lights were out in some parts of the Exhibition ; but if it was only three, he was very glad it was so few, but there were other dynamos there, the breakdowns of which were much fewer than three.

Mr. R. A. Lewis remarked that Mr. Parsons based his valuable information on a steam pressure of 90 lbs. per square inch. It would be interesting if the pressure was given at which the use of this generator would cease to be profitable. He believed a pressure of 50 lbs. could not be very favourable, since the exhaust pressure was rather high. He knew a case, where it was proposed to use this generator, where the pressure was only about 35 lbs., and in that case he was sure the machine would not work at a profitable speed. If Mr. Parsons gave them the quantity of coal burnt, or quantities of steam required at various pressures, to obtain certain power in this generator, that would help them to form a comparison.

Mr. Parsons, in reply, said at the last meeting Professor Garnett asked certain questions. The first was on what basis was the steam consumption of a perfect engine calculated? He had calculated this from Carnot's principle, making certain allowances, which he would explain.

Taking the temperatures of saturated steam at 90 lbs. and at atmospheric pressure, and 1 lb. of steam at 90 lbs. as containing 1002·4 units of heat from 212 degs. F., then the units of heat converted into work were 150·96, or 116541 foot pounds per pound of steam, and a consumption of just 17 lbs. of steam per horse-power per hour would be the equivalent amount of steam required,

As, however, in a steam engine working under these conditions there would be a large amount of condensation, and the exhaust steam would be wet, it would not be correct to take this as the standard of consumption. To prevent condensation it required an additional 11·46 per cent. of steam supplied to jackets or steam heaters, bringing the consumption up to 18·94 lbs. per horse-power per hour.

As, however, steam at or near the point of saturation behaved rather differently to a perfect gas, it would be safer to allow a small addition and to say that a consumption of steam of 20 lbs. per horse-power per hour was the unit for a perfect engine working with 90 lbs. pressure and exhausting into the atmosphere.

To illustrate this, he might say that one of the most perfect engines ever constructed and carefully tested was Messrs. Davy Paxman's compound engine at the Royal Agricultural Show at Newcastle. It worked at 150 lbs. pressure, the consumption of water passed through the engine in the form of steam was 17·13 lbs. per indicated horse-power per hour, adding, however, the jacket water, the total consumption was 19·53. The theoretical quantity necessary, excluding jacket water, was 13·68, about 14 per cent. additional was required for jacket water, giving a total of 15·59 lbs. per indicated horse-power per hour.

The theoretical consumption was therefore 79·8 per cent. of the actual consumption. The brake horse-power was 89·3 per cent. of the indicated and the coefficient of theoretical to actual was 71·26, or in other words, the engine gave 71·26 per cent. of the theoretical energy of the steam in brake horse-power.

Professor Garnett asked whether copper had been tried as the material for the commutator instead of gun metal. This, he might say, had once been tried and was now being tried again. It would probably be adopted for the larger sizes.

In regard to the arrangement of turbines for high-pressures, such as 150 lbs. per square inch, he would say that in the larger sized generators they had adopted an arrangement called the triple compound type. In this type the turbines or wheels increased in diameter by steps towards the exhaust ends. By this means the proper distribution of steam at very high pressures could be easily dealt with in a satisfactory manner.

The points on which there seemed to be most explanation required were the very important ones of the expansion of the steam in the turbines and how it acted, and as to the analogy between the water turbine and the steam turbine. He was very glad that Mr. Weighton had criticised the portions of his paper which dealt with these questions.

Mr. Weighton had drawn attention to some of the most important points, which enabled him to explain more fully some portions which he regretted had not been made clearer.

He could not agree with Mr. Weighton that any assumptions had been made which were not either proved in the paper or were generally accepted axioms.

Starting from the water turbine, which was thoroughly understood in every way, he had assumed an axiom which was given in all modern text books on the subject, viz., that for small difference of pressure gases obey the same laws when flowing through orifices as do liquids. He next dealt in detail with the distribution of steam in the series of turbines of each set, and showed where and under what conditions the expansion took place, and he had here to thank Professor Garnett for his very lucid explanation of the flow by comparing it to an elastic gas in a long tube, and he might point out that, in each short section of the tube, which Professor Garnett described, the gas behaved exactly as would a liquid, with the exception of a minute increase of volume at each section.

He would illustrate the expansion at each turbine by comparing it to the expansion that took place in a quadruple compound engine, where, instead of four cylinders, there were forty-five cylinders, each slightly larger than the preceding. He would compare the 70 per cent. efficiency spoken of in the paper with the compound engine with forty-five cylinders, with an assumed loss of 30 per cent. of power in each cylinder, arising from piston and valve friction and wire-drawing of the steam.

The indicator diagram or curve of expansion of such an engine would be the same as for the compound turbine, and be a wavy line following very closely indeed the adiabatic curve for steam.

The rapid increase of size and friction of the valves for high speeds in reciprocating engines did not occur in the steam turbine; and he did not think, therefore, that Mr. Weighton's analogy applied to the case.

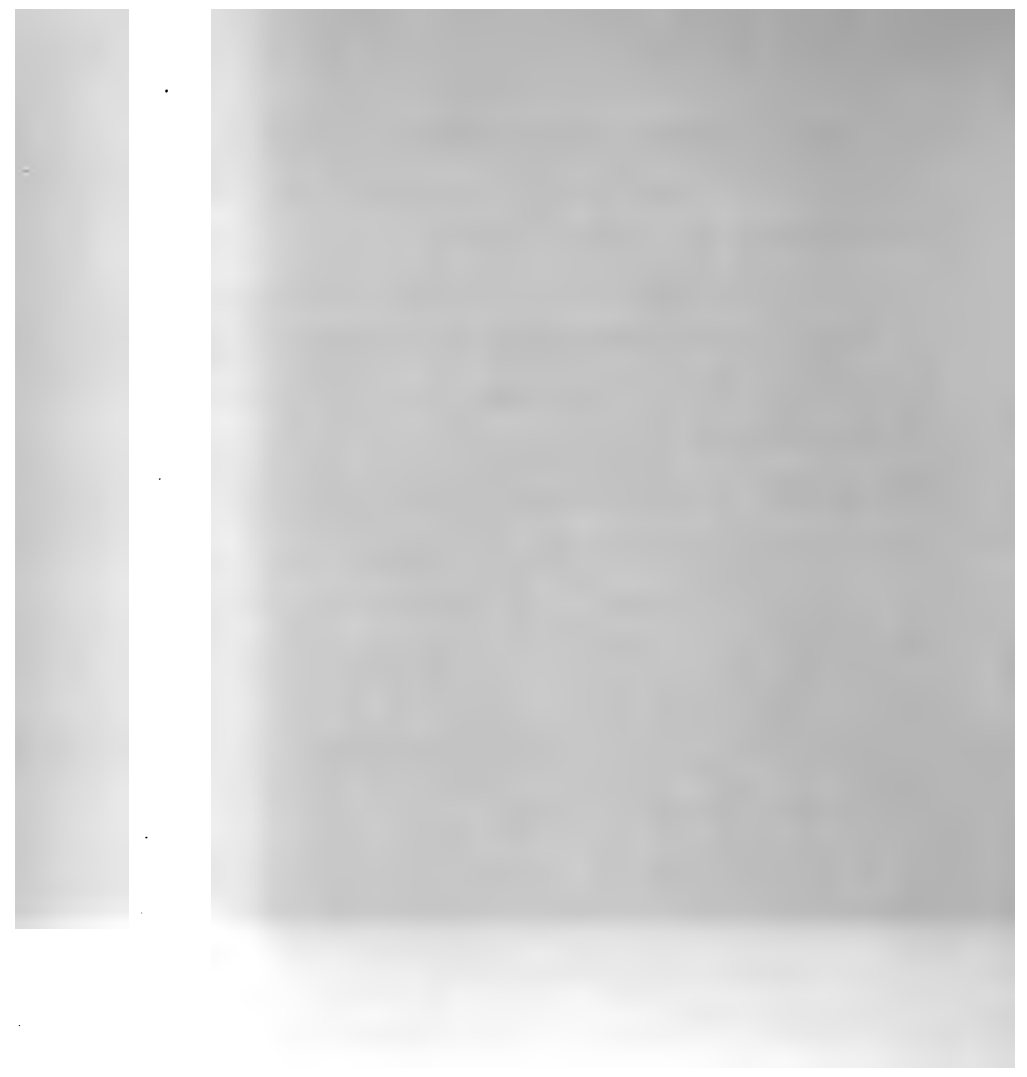
Mr. Sandison had asked whether the gyroscopic action of the revolving parts had any detrimental action in a sea-way. He would explain that they always placed the generators fore and aft in the ship, and when so placed the angular motion due to pitching was so slow that the extra force due to the gyroscopic action was not sufficient to cause wear on the bearings. He might say that so far they had not made generators for over 100 lbs. steam pressure, as there were very few places where higher pressures could at all times be obtained when required. He thanked Mr. Sandison for the suggestion in regard to calculating the indicated horse-power of the motor, which he thought a good one.

In reply to Mr. Holmes's question, whether wrought iron had been tried for the magnets, he might say that with cast iron magnets only $2\frac{1}{4}$ per cent. of the energy of the dynamo was used to keep up the magnetism, which was a very small loss as compared with other dynamos. If wrought iron were used, this loss might be slightly reduced; but the defect common to most dynamos, viz., difficulty in starting the magnetism, would be incurred. This defect necessitated some caution to see that the speed of the engine did not become too great before the magnetism took up, otherwise any lamps that happened to be on the circuit would be burnt up. This defect never occurred with cast iron magnets, which could always be relied upon to start at once.

The PRESIDENT thought they would agree with him in this, that the Institution was to be congratulated upon having had such an important paper brought before it. As far as he knew, this was a paper upon an entirely novel subject. Such an one had never been read before, and therefore had not only local, but universal interest. He would ask them to pass a hearty vote of thanks to Mr. Parsons for his paper, with acclamation.

The proposal was heartily reciprocated.

NOTE.—Mr. Parsons has since communicated that with a steam pressure of 84 lbs. per square inch a consumption of 42 lbs. of steam per electrical horse-power has been obtained.—ED.



ON THE COMBUSTION OF COAL AND SOME EVAPORATIVE EXPERIMENTS WITH NATURAL AND FORCED DRAUGHT.

By WILLIAM GEDDES SPENCE,
Member of the Council.

[Read before the Institution on January 11th, 1888.]

The application of forced combustion to steam boiler furnaces, especially for marine purposes, has lately so greatly occupied the attention of engineers, that on first thought the subject might be considered to have been just quite sufficiently discussed and criticised. However, notwithstanding the numerous excellent papers that have been brought forward, there does still exist a want of more fully detailed results from actual experience. It was in the hope of tending somewhat to reduce this want that the writer was requested by Mr. F. C. Marshall, of Messrs. R. & W. Hawthorn, Leslie, & Co., to undertake these experiments, and to lay the results, with any deductions therefrom, before this Institution.

Before proceeding to examine the experiments, it would perhaps be well first to review the general principles of combustion, and then to consider them in their application to boiler furnaces.

The combustion of coal consists in the rapid chemical combination of its combustible constituents, chiefly carbon and hydrogen, with oxygen. For steam boiler furnaces the only source of oxygen at present available is the atmosphere; which consists chiefly of a mechanical mixture of nitrogen and oxygen in ratio by weight of 77 per cent. nitrogen to 23 per cent. oxygen. Thus for every lb. of oxygen necessary for complete combustion $4\frac{1}{3}$ lbs. of atmospheric air are required; and hence we are compelled to introduce $3\frac{1}{3}$ lbs. of nitrogen, which, though not assisting combustion, has still to be raised from atmospheric temperature to that of the furnace, and on leaving the boiler carries away with it an amount of heat depending on the difference of temperature between the uptake and the atmosphere, and is thus simply an absorber of part of the heat produced by the combinations of the oxygen. To effect complete combustion the carbon and hydrogen must

be combined with oxygen so as to produce carbonic acid (3 units weight carbon to 8 units weight oxygen) and steam (1 unit weight hydrogen to 8 units weight oxygen), and therefore the exact quantities of oxygen chemically necessary are, 2·66 units weight per unit weight carbon, and 8 units weight per unit weight hydrogen. Taking the coal used in these experiments, an analysis of which will be found on Plate XXI., the total weight of oxygen necessary per lb. of coal will be—

$$O = 2{\cdot}66C + 8\left(H - \frac{O}{8}\right),$$

$$O = 2{\cdot}66 \times 0{\cdot}8051 + 8\left(0{\cdot}0424 - \frac{0{\cdot}0816}{8}\right)$$

$$O = 2{\cdot}1415 + 0{\cdot}2576$$

$$\therefore O = 2{\cdot}3991 \text{ lbs.}$$

and the air necessary to supply this will be—

$$2{\cdot}3991 \times 4{\cdot}33 = 10{\cdot}388 \text{ lbs.}$$

Professor Rankine in his work, *The Steam Engine*, states :—"It is unnecessary for practical purposes to compute the air required for the combustion of fuel to a great degree of exactness, and no material error is produced if the air required for the combustion of every kind of coal and coke used for furnaces is estimated at *twelve pounds per pound of fuel*."

Perfect combustion with this quantity of air is, however, only possible on a very small and experimental scale, where due attention and time can be given for perfect diffusion, and the bringing of each *atom* of carbon and hydrogen into what may be termed actual *mechanical contact* with its combining equivalent of oxygen. In practical operations on a large scale, such as steam boiler furnaces, the available time is so short and the conditions, even when at their best, under which the air can be introduced to the solid carbon and coal gas are so little calculated to help diffusion, that a greater quantity than is chemically necessary should be supplied to facilitate the combinations of the atoms. For a given percentage of combustible combining with oxygen, the less this surplus air the better; and with a given surplus this percentage of combining combustible is a measure of success in diffusion. Owing to the more searching nature of air from a blast under pressure, a smaller surplus is required when using forced draught; and on the authority of Professor Rankine this surplus may in the case of ordinary well-constructed boiler furnaces, be taken at 6 and 12 lbs. per lb. coal for forced and natural draught respectively; making, with the 12 lbs. chemically necessary, the total rate of air supply required for maximum efficiency = 18 and 24 lbs. per lb. of coal.

The principal products of these combinations are the following:—

Case I.—First, if the *total* quantity of air (that is, air chemically necessary plus air of dilution) containing the oxygen is just sufficient, neither more nor less, and its diffusion amongst the solid carbon on the bars and the hydrocarbon gases rising from the coal has been so complete that each *atom* of carbon and hydrogen is brought into *mechanical contact* with its combining equivalent of oxygen, then this oxygen combines with the hydrogen as it issues from the coal as gas in the proportion by weight of $\frac{8}{1}$ forming steam; the remaining oxygen combining with the carbon of the coal gas and the solid carbon on the grates in the proportion by weight of $\frac{8}{3}$ forms carbonic acid gas, intense heat being produced by and during these combinations. This steam, along with the carbonic acid gas, the nitrogen of the air which has had its oxygen chemically combined with the combustible constituents of the coal, and the remaining surplus quantity of air, pass up the chimney as colourless incombustible gases, the products of as perfect combustion as this ideal ordinary grate furnace would permit of; having produced in the boiler the greatest quantity of heat obtainable under the circumstances.

Case II.—Next, if the *total* air supply is deficient in quantity, but so introduced that its *efficiency of diffusion* is as perfect as in the first case—that is, that as great a percentage of its oxygen is taken up and usefully employed—then, as before, part of this percentage of the oxygen will combine with the hydrogen in the coal gas forming steam; the remaining percentage combines with part of the solid carbon and carbon of the coal gas in the proportion to form carbonic acid, while part of the liberated carbon, not finding its equivalent of oxygen, becomes deposited, and mechanically mixing with the steam forms smoke. Under this condition the total quantity of air to be raised in temperature is less than in Case I., but this is only obtained by a reduction in the number of atoms of combustible combining, and the total resulting temperature is lowered in proportion to the amount of carbon thus escaping uncombined with oxygen. The resulting products passing up the chimney from this condition of partial combustion are—carbonic acid, the nitrogen of the percentage of air that has been usefully employed, the remaining percentage of air that has not had its oxygen taken up, and steam containing solid carbon in mechanical suspension, rendering the escaping gas visible as the dark stream termed smoke, its intensity of darkness in colour depending on the proportion of solid carbon thus suspended.

Case III.—The air may also be so scantily introduced or, though sufficient, be so badly diffused that part of the coal gas escapes direct

into the chimney. Also part of the carbonic acid in passing up through or over the solid carbon on the bars may take up an additional quantity of carbon, thereby reducing it from carbonic acid, that is 3 parts carbon to 8 of oxygen, to carbonic oxide, namely, 6 parts carbon to 8 of oxygen, and if the latter be not supplied with sufficient oxygen to again raise it to carbonic acid, a diminution of temperature and loss of heat is the result.

Case IV.—In the above cases it has been assumed that the oxygen has been brought into contact with the carbon and hydrogen at the temperature necessary for their *immediate* chemical combination, but if the air supplied is more than sufficient (or even less, provided the efficiency of diffusion is not so great) a cooling effect is introduced owing to part of the heat produced by atoms that have combined being absorbed in expanding and raising the temperature of this unnecessary surplus.

So far as the experience of the writer is concerned, he has only found it possible to introduce air at the rates given by Professor Rankine when very great attention is given to its distribution, and the manner of introducing it, to and among the combustibles on and arising from the grates. The real practical difficulty in air introduction lies in this: that if each *atom* of carbon and hydrogen of the coal is not *first brought into actual mechanical contact* with its combining equivalent of oxygen it cannot combine with it, and is lost or worse than lost for the production of increased temperature. Thus we have seen in Case II. that if less air than is necessary is introduced, or in Case III. that the air, though sufficient in quantity, is introduced in such a manner that the atoms of its oxygen are not so diffused throughout the atoms composing the mass of the gases as to come into actual mechanical contact with each of these individual atoms of combustible, then part of them pass off unconsumed, and a decreased furnace temperature is the result. Also in Case IV., that if the arrangements for diffusion are perfect, but air is introduced in too great quantity, a decreased temperature is the result, for, as was shown, part of the heat produced is absorbed by the atoms that have not combined.

Thus the temperature of the products of combustion or evaporative efficiency of the coal may be reduced from three distinct causes.

1st.—Rate of air supply being deficient. Case II.

2nd.—Diffusion of air supply being defective. Case III.

3rd.—Rate of air supply being excessive. Case IV.

Or by two of these in combination, as, for instance, insufficient rate of supply and introduced in such solidity of stream that part escapes

without coming in contact with either carbon or hydrogen. It will thus be seen that correct *quantity* of air is merely one thing; what is equally important being the manner and place of its introduction, the measure of success being *the percentage usefully employed;* and when we consider the conditions obtaining in actual practice in boiler furnaces, the immense difficulty of proper, and practical impossibility of perfect diffusion becomes apparent. Take for example the boiler illustrated in Plate XIII. Here the combined area over the two bridges = 2·3 square feet, and total area through the tubes = 3 square feet. Now, assuming that the air is supplied at the rate of 24 lbs. per lb. of coal, and that the amount of coal burned = 250 lbs. per hour, the weight of air passing through the boiler per second $= \frac{250 \times 24}{60 \times 60} = 1{\cdot}66$ lbs; the temperature of the fire with this rate of supply should theoretically be about 2,500 degs. Fah., and if the temperature in the uptake = 600 degs. Fah., the mean temperature between furnace and uptake $= \frac{2{,}500 + 600}{2} = 1{,}550$ Fah., which would give a total volume of gases passing through the boiler approximately $= (12{\cdot}5 \times 1{\cdot}66) \times \frac{(461 + 1{,}550)}{493} = 84$ cubic feet per second, that is a velocity of about $\frac{84}{2{\cdot}3} = 36{\cdot}5$ feet per second over bridges, and of $\frac{84}{3} = 28$ feet per second through the tubes. The distance from centre of grates to outside end of tubes = 12·5 feet, therefore in a stream having a velocity of at least 28 feet per second there are available about $\frac{12{\cdot}5}{28} = 0{\cdot}45$ of a second of time for the complete diffusion of the atoms of another fluid throughout the atoms of its mass, and during this time it is very questionable if any further effective combinations take place after the gases have once entered the tubes.

The above calculation is necessarily a very rough approximation, as the temperature of the furnace would probably be less than 2,500 degs. Fah., and the correct mean temperature to use should not be the arithmetical mean between that of the furnace and the uptake.

The writer frequently noted with a stop watch the interval of time between a shovelful of coal dropping on a bright fire and the first appearance of smoke at the top of the chimney, this he found to vary from 3 to 4 seconds, and as the distance from grates to chimney top by the shortest route the gases could take = 48 feet, their mean velocity through both boiler and chimney must have been at least from 16 to 12 feet per second.

From this is apparent the necessity of having very careful arrangements for introducing the air in such a manner as to be as much as possible broken up into thin laminæ, jets, or whatever form is found to be most practically suitable and efficient for giving a maximum of surface from a minimum of quantity.

Of this air, part is required for combination with the solid carbon of the coal, and part for combination with the carburets of hydrogen or coal gas; the relative quantities necessary for each being in the proportion of 2·37 to 1.* And as it seems reasonable that the air containing the oxygen for combination with the gases will be better introduced to them direct, instead of first passing up through the coal on the grates and thus becoming diluted with carbon, the necessity for a well-distributed and plentiful supply of air above the grates is seen.

If the coal could be continuously and evenly fed on the fire it might be just possible that as much as this one-third of the whole air supply could beneficially be introduced direct above, the remaining two-thirds necessary for the solid carbon being brought through the grates from below, as then the state of incandescence of the fuel would continue regular, and the amount of coal gas given off per unit time would be a constant quantity; but in actual practice with hand firing (which when carefully attended to seems to hold its own against most mechanical appliances) the quantities of coal gas distilled are far from regular: being greater shortly after firing, and tapering away to little or nothing when the fire has become bright throughout or coked; at which period the only air necessary besides what would find its way up through the grates would be a quantity supplied direct at the top, and just sufficient again to raise to carbonic acid any gas that might have been reduced from acid to oxide in passing up through or over the coked fire. Thus at one period it appears as if one-third of the whole air supply could with advantage be introduced direct above the grates, and at another a less amount seems necessary; and as there has as yet been no satisfactory automatic arrangement for regulating the relative amounts, and as it has generally been found unsatisfactory to depend for it on the human element in firing; we seem left to the practical question of finding what relative openings for continuous supply are in actual work found to be the most economical mean between these two conditions.

The first result during and after placing a charge of fresh coal on a bright fire in a furnace is a reduction of temperature from several distinct

* Fairbairn's "Useful Information for Engineers," Appendix to Lecture IX., "On the Economy of Fuel, Concentration of Heat, and Prevention of Smoke."

causes; first, from loss of effect through the fresh coal lying on the top surface of the red fire, thus obstructing the radiant heat from striking the crown of the furnace; and, lastly and chiefly, from heat absorbed or rendered latent in changing the molecular condition of the coal from a solid to a semi-solid or viscous substance, and in distilling off the coal gas contained therein. If this gas on being released is brought into contact with sufficient air before its temperature has fallen below its point of ignition, its atoms of carbon and hydrogen combine with the oxygen of the air, and an increase of temperature is the result. But if air to supply a sufficiency of oxygen is not admitted, or the gas is allowed to travel till its temperature has fallen too low before meeting the air, a loss of heat is the result, as we then lose the whole heat which has been rendered latent in the work of distilling the gas, as well as that which the coal gas would supply if ignited. Also, if the air supplied from below the grates, in passing up through the coal should become so charged with carbon as to issue at the top surface in the form of carbonic oxide, an additional supply of oxygen must be given it by air admitted direct above the coal to raise it again to carbonic acid. If this be not done the carbon escapes in this half-burned state, and may not be readily observed, as, carbonic oxide being invisible, there is nothing to detect it by, unless it should meet sufficient oxygen in the uptake, or have still sufficient temperature left on reaching the chimney top, when, if this be the case, on there meeting the oxygen of the atmosphere it will combine with it and become visible as flame; and as carbonic oxide combines with oxygen at a comparatively low temperature, the effects of this are sometimes seen in practice by the interior of uptakes bursting into flames, or by fiery chimney tops. This carbonic oxide flame is of a blue colour, by which it can easily be distinguished from the ordinary red flame which may come into existence in the uptake by coal gas escaping direct through the tubes and only igniting in the uptake when meeting there its combining equivalent of oxygen. The former condition of affairs was very noticeable in trials Nos. 1, 2, and 3, Table 1, in which no air was admitted except such as passed in between the fire bars and up through the coal in the grates. On several occasions the uptake was observed to become completely full of a blue flame, and, with a view to more clearly recording this, the writer made the following notes of the appearance of the interior of the uptake as seen through a sight-hole during an hour and a half of the trial :—

P.M.

3 0 Fires thin and bright; flames some 2 feet long, of violet colour, floating gently from ends of tubes, and curling upwards towards chimney until

3 3 When flames disappeared, and interior of uptake became clear, with no smoke, till

3 4 When both fires were charged; uptake black, and now full of dense black smoke.

3 12 Both fires raked; slight red blush at first, but died soon after issuing.

3 17 Red flame, some 9 inches long, issuing from tubes, and continuing till

3 21 When uptake again became clear.

3 22 Both fires charged; dense black smoke, one or two short flashes appearing during charging, but becoming black again instantly.

3 27 Red flame coming from ends of tubes; light smoke from chimney.

3 33 Flames died away; no smoke.

3 34 Fires raked; slight red appears, but died away in a few seconds.

3 35 Red again appears from all tubes; flames this time terminate in violet.

3 35½ Violet part of flame considerably increased.

3 36 Flames red for about 6 inches from tube ends, tapering into violet, the violet part being about 3 feet long, curling up into chimney and waving about in an easy leisurely sort of way.

3 39 Flames from one-half of tubes (opposite east furnace) disappear; red part of flame from other part shortens and becomes lighter coloured and more yellow looking; violet portion also shortens and draws nearer to tube ends. Total length of flame (red and violet) now only about 12 inches.

3 40 Flame disappears; a few sparks keep coming through tubes till

3 41 When both fires were charged; thick black smoke; a few red flashes appear for a few seconds.

3 51½ Fires raked; uptake still black and full of smoke.

3 58 Red blush appears at ends of tubes.

3 59 Red flame, about 9 inches long, coming from tube ends.

4 1 Red flame now extending about 2 feet, and curling up chimney, its brightness gradually tones down to a dull red at the extremity, but the whole flame is red coloured throughout, with no appearance of violet.

P.M.

4 2½ Flames gradually dying away, only coming from about six or seven tubes.

4 4 Uptake black again.

4 8 Fires charged; uptake full of dense black smoke.

4 15 Red flames beginning to appear.

4 16 Red flames, about 12 inches long, coming from about half the tubes.

4 17 Fires raked; while door was open raking, whole interior of uptake filled with dull red glow.

4 18 Uptake black again.

4 20 Red flames beginning to appear.

4 21 Red flames, with violet tips coming from nearly all the tubes, violet rapidly increasing.

4 22 Whole uptake filled with flickering violet flame, except for about 3 inches from tube ends, which is red.

4 24 Violet flame, now toned down to sky blue, and only issuing from tubes immediately opposite furnaces, and curling up into chimney as far as can be seen from the sight-hole.

4 25 Flame now issuing from about six tubes only, and is composed, beginning from end next tubes, of about 3 inches red, 6 inches violet, and 3 feet sky blue. Total length of flame about 3 feet 9 inches.

4 26½ Faint greenish blue from one tube; yellowish green short flame from another.

4 28 Uptake black, except that two tubes keep issuing intermittent flames, about 6 inches long, of yellowish green tint.

4 29 Uptake black, with sparks coming through tubes; fires thin and very bright.

4 29½ Fires raked; shower of sparks through tubes, but uptake still black.

4 30 Fires charged; thick black smoke.

On one occasion, just before the violet flame commenced, the uptake temperature registered 750° Fah.; a few minutes afterwards, when filled with blue flame, the temperature as found by Siemen's pyrometer was 910° Fah., the fires not having been touched in the meantime.

From the above it will be observed that during the whole time there are indications of want of oxygen to the furnace, first after firing, by the emission and continuance of dense black smoke, next when the fires have become clear and even quite thin, by the appearance of the blue flame of carbonic oxide in the uptake, indicating that the oxygen of the air enter-

ing through the grates had been first converted into carbonic acid near the bottom of the fire, and then in passing up through, or over the bright coked fire had been reduced to carbonic oxide, falling in temperature in doing so, but had some additional air been supplied direct above the coal the combination of its oxygen with the carbonic oxide would have taken place in the furnace, raising its temperature by shortening the flame, and thus increasing the efficiency of combustion.

In heavy fires of some 12 inches thick this condition of affairs will not be improved by increasing the draught or pressure of air below the grates only, as by so doing the *rate* of combustion is only increased, and it will be found that within reasonable limits of pressure the *rate* of air supply to fuel remains practically unaltered. This fact the writer has noticed in firing some torpedo boat boilers of the locomotive type, where an even fire of some 12 inches thick was maintained, and trials conducted with pressures of air in the ashpit varying from 2 inches to 5 inches of water, no air being admitted direct above the grates except such as passed in while the doors were open charging. Throughout the whole of these trials the units air per unit coal, as determined by the amount of air entering ashpit, varied but little, and was in all cases below what is necessary for proper combination and dilution of both gases and solid carbon—that is for efficient combustion. The writer also found a similar result in the furnaces of a merchant ship boiler when burning thick fires of small coal on grates on the "Ferrando" system; in this case the fire bars were placed crosswise, and each $\frac{3}{8}$ inch thick, with $\frac{1}{16}$ inch air spaces, all the air being forced up through these at about $\frac{1}{2}$ inch pressure in the ashpits, the pressure in the furnaces and combustion chambers were so balanced by the chimney damper that on a door being opened no air entered, but the flame kept pulsating backwards and forwards in the doorway, being neither drawn in nor blown out.

And by keeping thin fires to *economically* bring sufficient free oxygen up through the fires for combination with the gases rising at the top is practically a very difficult proceeding, especially under forced draught, as then the pressure of air is very apt to burn the fire into holes; and the writer has frequently found after having had a fire carefully levelled and the fresh coal spread all over so as to make an even thickness of some 6 inches, that on opening the door some minutes afterwards the top surface of the coal would be a good deal caked, with here and there several cracks through which the air could be seen blowing strongly; and thus instead of coming up and issuing in equal amounts per unit surface it was introducing itself in a few dense streams, a method by no means

advantageous for easy and rapid diffusion; and probably the furnace was discharging into the uptake at the same moment both carbonic oxide and heated atmospheric air. By introducing the air for the gases direct to them at the top a more even state of incandescence throughout the mass of the fire is also obtained, this was particularly noticeable in trials Nos. 7 and 8, in Table 2, when a few holes only just above the doors were open, and the fires kept as thick as the high grates then in use would permit. On opening the doors some time after charging, the coals in way of the holes, and just where the air would strike, were always found quite red and charred, while the surrounding surface still remained black.

Under natural draught the difference even in the look of a fire supplied with a well distributed and proper supply of air is very marked. When the quantity of air is deficient, too great, or badly distributed: the deeper yellow coloured, long, trailing, smoky flame is seen; and this, though somewhat formidable in appearance, is much lower in temperature and far less efficient than the lighter coloured, shorter, clear, fiery-looking appearance obtaining in a properly regulated furnace.

In considering the best practical method of introducing the air direct to the gases several considerations must be kept in view; first, if introduced through the furnace fronts at A, Plate XIII., this has the advantage of passing it over the whole length of the grate, and thus having a greater length of run it gains more time for diffusion; the holes should, however, be well distributed, and kept as low in the fronts as possible, as there would appear to be some danger of air introduced at the top passing along just under the plate of the furnace crown. The fronts should be constructed of double plates, with the holes so arranged that nothing is lost through them by radiation.

If introduced through the top of the bridge at B, Plate XIII., it loses something in length of run, but has the advantage of entering the furnace at a point where all the gases must necessarily pass, and where there is always a high temperature; also, in issuing from the top of the bridge, the air is injected among the gases normally to their line of motion, which is a condition very favourable for assisting their diffusion. This method has, however, the disadvantage that the holes can be very easily covered over by any slag or clinker, which may find its way to and remain lying on the top of the bridge. It is also somewhat difficult to arrange a form of hollow bridge which would long stand the heat of the fire. Introducing the air through the bottom part of the back bridge at C, Plate XIII., has the advantage of its always being possible to see from

the stokehold if the holes are clear, but they should be kept as high up as possible, as dirt soon accumulates in the bottoms of the combustion chambers, and, in an ordinary return tube merchant ship boiler, this would eventually rise and cover the holes.

This question of diffusion also points to the very real advantage to be gained by large diameter furnaces and good combustion chamber capacity, as by having this, more space and time are allowed for the proper mixing up of the atoms of oxygen and coal gas: also, a small diameter furnace has the disadvantage that the flame, coming into direct contact (or as near direct contact as flame can be made to assume) with the metal of the furnace, having water at a comparatively low temperature on the opposite side, becomes cooled, and smoke is consequently produced. In actual marine boilers it is a practical impossibility to get as great a diameter of furnace, or anything like as much combustion chamber capacity, as would be deemed necessary if only the question of perfect combustion had to be considered, as for this purpose the flame ought never to reach the metal at all, but due attention being paid to actual practical requirements, the larger the diameter of furnace, and the greater the combustion chamber capacity the better.

In the class of boiler used in these experiments it would have been advantageous for efficiency of combustion to have introduced a hanging bridge, or baffler behind the fire bar bridge H, Plate XIII., against which the gases on striking, and in being deflected downwards, would have become more thoroughly diffused. This would, at the same time, however, tend to check the draught, and though favourable for efficiency, would have slightly reduced the rate of evaporation.

Having thus traversed some of the general principles of combustion in furnaces, it remains to describe the method of conducting the experiments, and observe how far these principles have been borne out by the results.

The boiler employed is shown in Plate XIII. It was only a little over eighteen months old, and was fairly clean and in good condition throughout. The whole circumferential surface was clothed with about 2½ inches of non-conducting cement, the front end being the only surface left exposed to radiation. It supplied steam for driving several small engines, the pressure being kept steadily at 55 lbs. per square inch above the atmosphere, and the surplus steam blown off by a special relief valve or the safety-valve. The escaping steam always appeared quite dry, and there was no appearance of priming.

A very good idea of the appearance of the coal used is given by

Plate XXI., which is taken from a photograph of a fair average sample. On this plate will also be found the ultimate analysis and absolute calorific value, as certified by Mr. Pattinson, the Borough Analyst, from carefully selected samples from fourteen separate trials. The coals were always got from the same colliery, they varied but little in size or quality, and were fairly free from dirt and dust. They were weighed out on a small Pooley's weigh table, which was frequently checked by standard 56 lb. weights. Before beginning each trial the fires were burned very low and quite clear. Their condition was then carefully noted, and at the finish they were burned down and left at the same level and condition. For a series of comparative trials, such as those required for the purposes of this paper, this method is quite good enough; but in trials intended purely to determine the efficiency of a boiler and available calorific value of coal, it would be better to empty the grates both before and after each trial, as the results got by the method adopted are throughout slightly higher than the correct amount, owing to the fact that although each experiment is begun and ended with fires of the same thickness and apparent brightness, yet, at the finish, they contain a greater percentage of ash and clinker than they did at the beginning. Owing, however, to the clean nature of the coal used, the quantity of clinker in the fire at the conclusion of each trial was not very great.

The same fireman was employed throughout the experiments, and level fires were worked. They were disturbed but little; the charges varied from 56 to 82 lbs., and were spread evenly over the grates, then left for some time, when they were turned up and levelled with the rake, and left till ready for a fresh charge. The slice or pricker was never used, and both fires were either charged or raked at the same time.

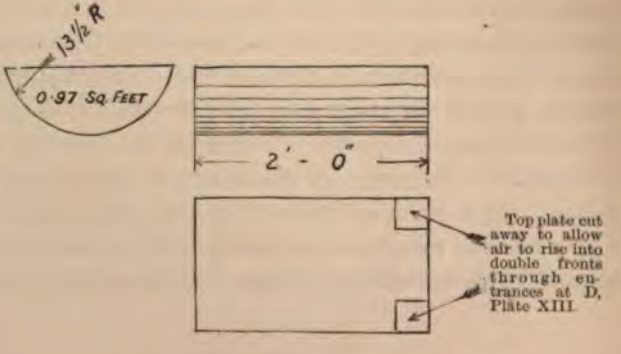
The tubes were cleaned previous to every trial.

At the commencement of each trial the height of water in the gauge glass was marked, and at the finish it was left at the same level. The total evaporation was measured by the feed water which was drawn by the donkey pump A, Plate XIV., from the barrel B, this barrel was supplied from the measuring tank C, and was filled to the brim before starting, and run up to the same point at finish of trial. Then the number of fills of tank C, plus the amount that the level of water left in it was below brim at finish, gave the total water evaporated at boiler pressure from feed temperature. The water for this tank was supplied through an india-rubber hose, so slung up that on the tank being filled the end of the hose was swung round outside where it could always be seen, and thus no leakage passed in between fillings. The drain pipe D from the boiler

water-gauge was carried into barrel B, and thus any water blown out through it was pumped again unmeasured into the boiler.

Taking first the natural draught series (Table 1), the guiding idea in these was to keep the firing as similar as possible in all the experiments, and by varying the rate of air admission above the grates to note what effect this had on the efficiency of combustion. For this purpose each furnace front was fitted with 44 air holes, tapped $\frac{5}{8}$ inch diameter (A, Plate XIII.), so that by inserting screw plugs, the number of open holes could be regulated or abolished. The bottom part of each back bridge was fitted with 7 holes $\frac{3}{4}$ inch diameter (C, Plate XIII.), the whole or any number of which could also be stopped up. On the parts of the grates which were bricked over, the boxes B, Plate XIII., were placed; these, being open at the bottom and having each 24 holes $\frac{5}{8}$ inch diameter in the top, allowed air to rise direct from the ashpit to the coal gas as it passed. These boxes were only put in place in the trials where they are shown in column No. 32, as having been open; in all the others where no air is shown as being admitted through the top of bridges, they were removed for fear of leakage and the spaces built up with firebrick. In taking the temperatures for the curves shown in Plates XVIII., XIX., and XX., the holes in the tops of these boxes were closed by laying on them a $\frac{1}{2}$ inch iron plate, which could be instantly put in place or removed and pulled through the fire doors. Also in taking these curves, the holes in the furnace fronts instead of being individually plugged up by screws, were closed by having plates placed across the main entrances for air at D, Plate XIII., these plates were kept close up and air tight by shores from the ground, which could be instantly knocked out and air admitted through all the holes in the fronts. The number and position of air holes open in each trial is shown in columns Nos. 30, 31, 32, Tables 1, 2, 3, and 4, and the ratio of their collective area to that of the open space through the grates, is given in column No. 35.

Each ashpit was fitted with a sheet iron mouthpiece, thus :—



fitting closely to the deadplate and boiler. All the air, both for direct supply above the grates and for passing up through the fire, had to enter through these mouthpieces, and the velocity of the current through each was taken every 15 to 30 minutes by two anemometers, both being lashed on the end of a long light crutch, which permitted of the operator standing some 4 feet back from the mouthpiece, and moving them all over the section of the tube. Each reading was the mean of a 3 to 4 minutes' record. The anemometers were several times checked by Messrs. Winter & Son, opticians; the writer also twice checked them by fastening them to the end of a wooden lath, and having them revolved horizontally at 6 feet radius in a large room free from draughts, at velocities similar to those at which they were used. In all cases they were found to be practically accurate. In using them both at once in the way indicated the one formed a check upon the other, and their respective readings seldom differed by more than 2 per cent. The mean temperature of the atmosphere, as given in column 4, was got from half-hourly readings taken from a thermometer hung in the shade and protected from radiant heat, and from this temperature and the mean of the anemometer readings the lbs. air per lb. coal given in column 38 were calculated. For convenience, the diagram given in Plate XVII. was constructed, from which the rates of volume to weight of air can be read off for any temperature from 0 deg. Fah. to 350 degs. Fah. The temperature in the uptake was got from half-hourly readings taken with a Siemen's pyrometer kindly lent to the writer by Mr. Alexander Taylor. To this method there was the objection that the range of variation in temperature was so considerable that there was no certainty that half-hourly readings would give a fair mean. With a view to overcoming this uncertainty a series of trials were conducted, during which the temperatures were taken every minute from a pyrometer having a dial like a steam gauge, the index hand of which was moved round by the expansion of rods, from which the temperature at any instant of time could be read. These temperatures were also checked by half-hourly readings taken with the Siemen's pyrometer, the copper cylinders of which were carefully weighed, and the temperature worked out from this and the rise in temperature of a known weight of water. In taking the temperatures as given in Plates XIX. and XX., the pyrometer was inserted at E, Plate XIII., so as to be out of reach of flame from the tubes; for those given in Plate XVIII., and in columns 26, 27, 28, Tables 1, 2, 3, 4, it was inserted at the point F, and these latter can hardly be relied on as a fair guide to the mean temperature of the uptake. In the curves on Plate XVIII. it was observed that when the holes at A, Plate XIII.,

were opened the range of variation of temperature decreased (as shown in curve B) below what it had been with no air direct to gases (as in curve A); it still further decreased on opening out the holes at C, Plate XIII. (as shown in curve C), but on further increasing the air to gases, by also opening out the boxes B, the range of variation rose considerably, as per curve D. It was likewise noted that when little air was admitted direct to the gases, as in curves A and B, a short and sudden rise of temperature occurred in the uptake on opening a fire door to charge a furnace, but that when a larger supply (as per curves C and D) was admitted, a sudden drop in uptake temperature was the immediate result of opening a door. The curves given on Plates XIX. and XX. also show similar results. The mean temperature was found to be practically alike in all the curves A, B, C, and D, Plate XVIII. This the writer put down to the fact that as a trial proceeds the fires dirty up and evaporation decreases; and thus one single experiment could hardly be deemed satisfactory, as the conditions tried towards the end would show a relative diminution of temperature from this cause. And had the order of precedence been D, C, B, A, it would probably have been found that a higher mean temperature was obtained with air admitted direct to the gases. With a view to determining this, another series of trials were held on two successive days, as given in Plates XIX. and XX., in which the conditions each day were exactly similar—only, that on the first day (Plate XIX.) the air supplied direct to the gases was gradually increased, whereas on the second (Plate XX.) it was gradually diminished; thus the means of the two days should give a good index of the actual effect under each condition of air admission direct to gases. During these trials the duration of smoke was noted, and is indicated by the last column in the table of mean results on Plate XX. From the curves and the table it will be noted that as the air direct to the gas is increased *the mean temperature rises, the smoke diminishes both in intensity and duration, and the water evaporated per lb. of coal increases.*

The practical arrangements in these fronts and bridges unfortunately did not permit of the air supply to the gases being increased till it was more than sufficient, and thus the turning point between sufficiency and excess is not shown.

From column No. 42, Table 1, it will be noted that as the rate of air supply to gas is increased the efficiency of combustion rises, the difference between no air opening above and a ratio of $\frac{1}{24}$ being 11·8 *per cent. increase in favour of air direct above.* Also when no air was admitted direct to the gases the chimney emitted large volumes of dense black

smoke similar to that marked No. 1 in Plate XXII. lasting for about 3½ minutes, this was followed by from 1½ to 2 minutes of smoke similar to that marked No. 2, and then taking from 3 to 3¼ minutes to die away from No. 2 to transparency as shown in No. 3, the total duration of smoke being some 8 minutes, by which time the fires were about ready for raking, which again sent up a fresh supply, and by the time this had died away it was nearly time to charge again, so that the chimney was only free from smoke for a very small percentage of the total time of trial. The particulars of the smoke, as given in columns Nos. 38, 39, 40, and 41, were got from about five or six observations taken during every trial, the fire being allowed first to become quite clear, and then three shovelfuls of coal being spread evenly on each grate the intensities and duration of the smoke were noted, and the mean of the several observations placed in Table 1.

The conclusions to be drawn from Table 1 appear to the writer to be :—

1.—That it is impossible to obtain satisfactory combustion in furnaces having the whole air supply drawn up from the ashpits through the fires.

2.—That with an arrangement of grate similar to that used in these experiments a collective area of not less than $\frac{1}{34}$ to $\frac{1}{70}$ of the open space between the fire bars should be allowed for the admission of air direct to the gases. That this area should be made up from holes $\frac{5}{8}$ inch or at most $\frac{3}{4}$ inch diameter spread over the furnace fronts, doors, and bottoms of back bridges.

3.—That, even having this provision for air supply, with the thickness of fire necessary in practice, it is extremely difficult to get a rate of air supply of over 20 lbs. air per lb. of coal, and that the chances of the air supply being deficient are much greater than that of its being excessive.

4.—That with a sufficient and properly distributed supply of air direct to the gases, the same rate of evaporation can be obtained from a boiler as with the air passing up through the fires only. That the coal consumption will be reduced some 10 per cent., while the smoke will be diminished fully 50 per cent. both in intensity and duration.

The above remarks refer to North Country coal of fairly good quality and to boilers working at moderate rates of evaporation, say 5 to 6 lbs. water from and at 212 deg. Fah. per square foot heating surface per hour, with a rate of combustion of about 17 lbs. coal per square foot grate

per hour. With Welsh coal the rate of air supply direct to the gases might probably have to be somewhat reduced, but would still remain a very considerable amount.

Turning now to the forced draught series, the intention there was to keep the rates of evaporation as nearly similar as possible to those that had been worked under natural draught and note the efficiency of combustion, first, when using forced blast at atmospheric temperature, and then with the blast heated to as high a temperature as probably could be attained by any apparatus of reasonable dimensions for utilising the waste heat of the escaping gases in the uptake. The blast was created by a combined fan and engine E, Plate XIV., kindly lent for the experiment by Messrs. Donkin & Nichol. The air from this fan was first driven through an air heater F, Plate XIV., and passing into the main duct G entered the closed ashpits and fronts by the branch pipes H. The volume of air used was measured by an anemometer placed at the point J in the exit pipe of the air heater. The air during the hot blast trials was measured in the same manner and its temperature got by a mercurial thermometer hung in the centre of the main duct about the point G. This arrangement prevented any discrepancy in the apparent temperature due to radiation from surrounding bodies, and the temperature obtained was that of the air alone. A section and plan of the air heater is given in Plate XVI.; it was constructed from the bottom tier of tubes of an old Roots' boiler which had some time before been dismantled at Messrs. Hawthorn's St. Peter's Works. It consisted of a cast iron entry pipe A, 9 inches inside diameter; this was connected to the exit pipe B, which was also of cast iron and 10 inches inside diameter by twelve wrought iron pipes C, each 5 inches inside diameter, the whole was enclosed in the sheet iron case or house D, containing the grate E, and fitted with a chimney F. In all the trials the air passed through these tubes, only that during the hot blast series, Table 4, a strong coke fire was kept burning on the grate E, which raised the temperature of the passing air to that given in column 29, Table 4, which is the mean of half-hourly readings taken from the thermometer at the point G.

Taking first Table 2, in this series the grates used were the same as had been employed for the natural draught trials as shown in Plate XIII. On these it was found impossible to obtain any satisfactory results. Owing to the small diameter of the furnaces the fires could not be kept thick enough to prevent their being burnt into holes. In endeavouring to reduce this evil the small space left between the coals and the furnace crown precluded any chance of satisfactory combination of oxygen with

the gases from the coal, and even under these circumstances, and the area for air direct to the gases reduced to $\frac{1}{150}$ of the open space through grates, with grates 1 foot 10 inches long and an air pressure of 0·625 inch water in main duct G, the rate of air supply was 20·7 lbs. air per lb. coal as in trials Nos. 7 and 8. The open space between the fire bars in the grates amounted to $\frac{1}{2{\cdot}5}$ of the whole grate area, and owing to this and the restricted space between the fires and the furnace crowns a considerable amount of flashing back occurred on opening the fire doors. The best results obtained were those in trials Nos. 3 and 4, when a mean of 9·57 lbs. water per lb. coal was evaporated from and at 212 degs. Fah., giving an efficiency of 0·678. This result was got with an area for direct air supply to gas of $\frac{1}{31}$ of the total open space among fire bars, and a rate of total air supply of 26·6 lbs. air per lb. coal. The highest efficiency obtained under natural draught was 0·727 or 7·2 per cent. better than the forced draught results.

From the results of the ten trials given in Table 2 it was concluded that no satisfactory results could be obtained in these furnaces on grates as shown in Plate XIII. It was, therefore, decided to remove the fire bars and fit others having a much smaller percentage of open space between them. By doing this and lowering their level considerably below the centre line of the furnace, it was hoped that the supply of air from below would be so curtailed as to allow of a proper amount of air being supplied direct to the gases, still leaving the total rate of air supply not more than 18 or 20 lbs. air per lb. coal. The grates shown in Plate XV. were therefore fitted, in these the line of fire bars was dropped down to 5 inches below the centre line of furnace. By this means a fire of some 11 inches thick could be maintained, and still leave a reasonable amount of space between the coal and the furnace crown. The fire bars were $\frac{3}{8}$ inch thick, having air spaces $\frac{1}{16}$ inch wide, giving a total open space between bars of $\frac{1}{7}$ the total grate area, instead of $\frac{1}{2{\cdot}5}$ as formerly. Owing to the lowness of the grates and the consequent difficulty of making satisfactory longitudinal side bars the fire bars were placed crosswise as shown at A, Fig. 2, Plate XV. The results as got on these grates with forced blast at atmospheric temperature are given in Table 3. Trials Nos. 1-2 give results as got by working the boiler at about natural draught rates of evaporation, the grates being reduced so as to make the rate of combustion 39·5 lbs. per square foot grate per

hour and ratio of heating surface to coal = 1·56. *No air was admitted direct to the gases*, and the total rate of air supply = 17·1 lbs. air per lb. coal. The water evaporated per lb. coal from and at 212 degs. Fah. = 9·41 lbs., giving an efficiency of 0·667. The smoke lasted for 7¾ minutes, 3 minutes of which were of No. 1 intensity. The results got from natural draught with no air direct to gases = 9·166 lbs. water from and at 212 degs. Fah., giving an efficiency of 0·65 ; so from this the results due to the forcing of the combustion would appear to have been as $\frac{0·667}{0·65}$ or 2·6 per cent. in favour of the forced draught.

In trials Nos. 3 and 4, 29 holes $\frac{9}{16}$ inch diameter were opened round each door at A, Plate XIII., giving a total area for air direct to gas of 14·38 square inches, being rather better than one-tenth of the total open space between the fire bars. The rate of combustion was 37 lbs. coal per square foot grate per hour, and the heating surface per lb. of coal was 1·66 square feet. The rate of total air supply was 20·3 lbs. air per lb. coal, and the water evaporated from and at 212 degs. Fah. 10·675 lbs. per lb. coal, giving an efficiency of 0·757 ; the smoke lasted for four minutes, and was never of greater than No. 3 intensity. Comparing these trials with Nos. 1 and 2 the efficiencies are as $\frac{0·757}{0·667}$, or 13·5 per cent. in favour of the air supply direct to the gases. The best results got under natural draught were those in trials Nos. 29-30-31, Table 1, when 10·25 lbs. water were evaporated from and at 212 degs. Fah. per lb. coal, giving an efficiency of 0·727, or $\frac{0·757}{0·727} = 4·1$ per cent. in favour of the forced combustion. In trials Nos. 5–6–7 the opening for air to the gases was increased to rather more than one-seventh of the open space through the grates ; with this ratio of opening a rather lower efficiency was obtained. The purpose of trial No. 14 was to keep the ratio of heating surface to coal the same as in trials Nos. 3–4, 5–6–7; but to increase the rate of combustion to 47·5 lbs. coal per square foot grate per hour by reducing the area of grate from 7·2 square feet to 5·8 square feet, and increasing the pressure of air in ashpit to 0·66 inch of water.

In trials Nos. 17 and 18 the ratio of heating surface to coal was also kept about the same, and the rate of combustion per square foot grate reduced to 31·5 lbs. per hour by increasing the grate surface to 8·25 square feet and reducing the pressure of air in the ashpit to 0·3 inch of water. In neither of these series was so high an efficiency reached as that got in trials Nos. 3 and 4. The intention of trials Nos. 8–9,

10–11, 12–13 was to show at what rate the efficiency would fall consequent on increased rates of evaporation.

In Nos. 15 and 16 the rate of evaporation was decreased below that of Nos. 3 and 4 to observe what increase of efficiency would follow.

In the hot blast trials Nos. 1–2–3, 4–5, Table 4, the ratio of heating surface to coal was kept as nearly similar as possible to that in trials Nos. 3–4, 5–6–7, in Table 3. The best results obtained were those in trials Nos. 1–2–3, where the rate of combustion was 34·75 lbs. coal per square foot grate per hour with 1·77 square feet heating surface per lb. coal, the rate of total air supply being 18 lbs. per lb. coal, at a pressure of 0·338 inch water in the ashpit, and a temperature of 261 degs. Fah. The area allowed for air direct to gas was $\frac{1}{6{\cdot}8}$ of the total open space through grates, and the smoke lasted for five minutes, never being of more than No. 2 intensity. The water evaporated from and at 212 degs. Fah. was 10·74 lbs. per lb. coal, giving an efficiency of 0·761, or an increase of $\frac{0{\cdot}761}{0{\cdot}757} = 0{\cdot}53$ per cent. in favour of the heated blast.

In trials Nos. 4 and 5 the ratios of heating surface to coal were kept the same as in trials Nos. 1–2–3, but the rate of combustion was decreased from 34·75 to 30·38 by increasing the grate surface from 7·2 to 8·25 square feet, and decreasing the pressure in the ashpit from 0·338 inch to 0·24 inch water. The results got were practically equal in efficiency to those of trials Nos. 1–2–3. Trials Nos. 6–7 were carried out to compare with trials Nos. 15–16 in Table 3. The water evaporated per lb. coal was 11·06 lbs. from and at 212 degs. Fah. per lb. coal, giving an efficiency of 0·784, or $\frac{0{\cdot}784}{0{\cdot}755} = 4{\cdot}1$ per cent. in favour of the heated blast.

In making the above comparisons between forced and natural draught, the writer has made no allowance for steam used in driving the fan to create the blast, which when taken into account will slightly reduce the percentage gain shown in favour of forced draught.

The chief points that seem to the writer to be indicated by Tables Nos. 2, 3 and 4 are:—

1st.—That they bear out the natural draught, Table 1, in this, that a very considerable area for air direct to the gases must be supplied to insure efficient combustion and reduce smoke.

2nd.—That in designing a grate for forced draught the ratio of open air space between fire bars to total grate surface should be much less for forced than for natural draught.

3rd.—That a moderate air pressure of about 0·4 inch water in the ashpit, giving a rate of combustion of about 35 lbs. coal per square foot grate per hour seems more economical than greater air pressures with increased rates of combustion.

4th.—That by the use of moderate forced blast a higher efficiency of combustion is obtainable than by using natural draught simply.

5th.—That in order to make a commercial success of any arrangement for raising the temperature of the air for combustion by the waste heat of the escaping gases, the heater would require to be very efficient and of small first cost and up-keep.

It seems strange that in the present state of keen competition bringing into existence endless kinds of apparatus for increasing the fraction of practically available heat from steam when once generated, that so little effort is generally made to improve the design of the furnace for generating that steam; although the benefits to be derived in this direction were very fully laid before engineers as early as the year 1841 by the late Mr. C. Wye Williams, to whose works the writer is indebted for much guidance in this matter. It is quite within the mark to say that, at the present moment, by far the greater number of marine boiler furnaces have no provision whatever for burning the coal gas they generate, as the little air that is admitted direct above the grates is quite inadequate for the volume of gas generated from North Country coal, and is seldom even sufficient for the quantity that would be necessary for a coke fire. This is a matter of particular importance in this district, for, by this fact, Welsh steam coals, containing a smaller percentage of volatile combustible constituents, obtain an undue superiority. There seems a general concensus of opinion among engineers that a considerable reduction in consumption results from using best Welsh in place of best North Country coals. But the mean absolute evaporative value of the two cannot be placed at a higher ratio than $\frac{15}{14{\cdot}625}$ or 2·5 per cent. in favour of the Welsh; and the writer would here venture the opinion that a very appreciable fraction of the advantage usually claimed for Welsh coal is due to the fact that, as a rule in practice, just the same amount of air is admitted direct above the grates in both cases, whereas for North Country coal a considerably greater amount is necessary. It also appears to the writer (and the annexed experiments seem to bear this out) that of the saving which has already been actually obtained in

practice by the application of forced draught, a considerable portion must be credited to the more enlightened methods of air introduction, which the advocates of this system have usually introduced when fitting their forced draught apparatus, and that the economy due to the forcing of the draught *per se* (namely, reduced air supply and increased mean temperature between furnace and uptake giving more rapid transmission of heat through the plates), is not so considerable as it would seem when merely looked at in a general way. For instance, had a system of forced draught, giving results similar to those got in trials Nos. 3–4 in Table 3, been fitted to a boiler under natural draught similar to trials Nos. 1 and 2, Table 1, the increase of efficiency would have been in the proportion of $\frac{10{\cdot}67}{9{\cdot}166}$, or a clear saving of 16·4 per cent. in favour of the forced draught; and had a system similar to that given in Table 4 been adopted, the saving would have been $\frac{10{\cdot}74}{9{\cdot}166}$, or 17·1 per cent. in favour of heated forced draught, with the entering air raised to 261 degs. Fah. But when the natural draught results, as per trials Nos. 29–30–31, Table 1, are taken as the basis of comparison, the relation between the two is for cold forced draught as $\frac{10{\cdot}67}{10{\cdot}25} = 4{\cdot}1$ per cent. gain, and for heated forced draught as $\frac{10{\cdot}74}{10{\cdot}25} = 4{\cdot}78$ per cent. gain.

It is certainly not the intention of the writer to give the above as the best relative results that may be expected, as much better methods of applying forced draught probably are and certainly will be adopted; and it must not be forgotten that the boiler experimented upon was designed with a view to being used under natural draught only, and with more extended experience and a boiler got out especially for forced draught better results might be looked for. Also, besides the small saving shown above, the principle of artificially forcing the combustion has several important bye-advantages: first, it renders the furnace practically independent of weather and climate, as the air necessary for full power evaporation is always at command, and many natural draught marine boilers steam but poorly with a light following wind, under which circumstances the fires have to be unduly worked, causing considerable waste; also, a very cheap and inferior quality of coal can be burned effectually and the boiler kept at full power; and, lastly, there ought to be some slight gain in increased speed of vessel, as steam can be maintained steadily by shutting the blast off from a fire during cleaning, and increasing the air pressure to the other furnaces,

which advantage appears quite tangible when we consider that most cargo boat engines have either to be linked up during cleaning fires, or suffer a loss of pressure, and that sometimes it is nearly an hour before the pressure is fully regained, which, with six furnaces and each fire cleaned once every twenty-four hours, means that practically the ship is worked at reduced power for 25 per cent. of her steaming time.

The above results seem to the writer to point to the desirability of having a series of reliable public trials conducted by an engineer of recognised reputation and ability; and if this Institution could have any influence to induce the Executive Committee of the late Newcastle Industrial Exhibition to apply to this purpose part of any surplus funds they may have left at their disposal it would certainly be a great step in the right direction. Say two similar type boilers were tried, one fitted up as best suited for natural draught and the other designed expressly for forced draught, and let them both be steamed for say twelve hours per day for ten days, an equal amount of water being evaporated by each, each day, and the difference in coal consumption measured, or an equal weight of coal to be burned by each, each day, and the difference in evaporation measured. If these trials were undertaken it would be interesting to have arrangements made for introducing the air for passing up through the grates and that direct to the gases by separate pipes in which anemometers could be placed, and the *relative weights* of air being supplied up through the fire, and direct to the gases thus determined.

If to the above trials could be added an open competition of the various practical methods of applying forced combustion as at present before the public, coupled with a prize from North Country colliery owners for greatest freedom from smoke, this paper would, in the opinion of the writer, have done some service, and the results thus got from public trials, certified by a recognised authority, would do much to place in a fuller and truer light the relative merits of two systems of combustion which are at present viewed by members of the engineering profession with very varying degrees of confidence.

The PRESIDENT said the discussion upon this important paper would be adjourned until their next meeting on the 8th February. The writer had thrown out a very good suggestion, which perhaps between this and next meeting would be considered by those members of the Executive Committee who happened to be in the room. It was a very important subject; and if there was a large surplus, it possibly could not be better used.

SULTS

ASHES.		KE IN MINUTES.					REMARKS.	
	Per Centage.	Sq. Ft. Heating Surface per No. 2. (See Plate XXII.)	No. 3. (See Plate XXII.)	Total Duration.	Efficiency, taking Calorific Value of Coal at 14°1, as determined by Thompson's Calorimeter. (See Plate XXI.)	No. of Trial.		
	17A	139	40	41	42			
0	1·36	1·66	3·16	8·32		1	29 Fire Bars, ½ inch thick, in each Furnace. Uptake several times full of blue flame.	No Air direct to Gases.
75	1·17	1·7	3·2	8·25		2		
5	1·14	1·0	3·375	8·875		3		
32	1·22	1·78	3·245	7·94	0·65	MEAN		
25	1·12	1·0	3·1	8·3		4	29 Fire Bars, ½ inch thick, in each Furnace.	Air to Gases through Bottom Part of Bridges at C. (Plate XIII.)
0	1·18	1·375	3·7	8·375		5		
0	0·97	1·...	...	...		6		
4	1·09	1·687	3·4	8·33	0·657	MEAN		
0	1·07	1·45	2·55	6·3		7	29 Fire Bars, ½ inch thick, in each Furnace.	
75	1·34	1·7	2·8	7·58		8		
0	1·19	1·...	...	...		9		
9	1·2	1·57	2·675	6·94	0·664	MEAN		
25	1·05	1·94	2·81	6·81		10	29 Fire Bars, ½ inch thick, in each Furnace.	
75	1·64	1·66	2·5	6·5		11		
0	1·406	1·7...	...	...		12		
3	1·365	1·8	2·65	6·65	0·658	MEAN		
5	1·41	1·66	2·55	6·66		13	29 Fire Bars, ½ inch thick, in each Furnace.	Air to Gases through Bottom Part of Back Bridges at C, and through Furnace Fronts at A. (Plate XIII.)
0	1·56	1·7	2·0	6·5		14		
5	1·27	1·...	...	...		15		
3	1·48	1·68	2·12	6·58	0·671	MEAN		
0	1·6	1·5125	3·375	6·125		16	29 Fire Bars, ½ inch thick, in each Furnace.	
0	2·01	1·4625	2·81	5·18		17		
0	2·54	1·7...	...	5·53		18		
7	2·05	1·6875	3·092	5·612	0·682	MEAN		
0	2·65	1·625	2·56	4·83		19	29 Fire Bars, ½ inch thick, in each Furnace.	
25	2·18	1·0	3·75	5·33		20		
5	1·97	1·...	...	6·0		21		
91	2·27	1·8125	3·2	5·39	0·686	MEAN		
25	2·38	1·0	3·75	5·33		22	29 Fire Bars, ½ inch thick, in each Furnace.	
5	1·91	1·5	3·5	5·0		23		
0	2·01	1·...	...	...		24		
25	2·1	1·925	3·625	5·16	0·71	MEAN		
5	2·65	1·80	3·375	3·375		25	29 Fire Bars, ½ inch thick, in each Furnace.	Air to Gases through Bottom Part of Back Bridges at C, through Furnace Fronts at A, and through Boxes at B. (Plate XIII.)
5	2·11	1·7165	4·0	4·165		26		
5	1·9	1·7...	...	...		27		
16	2·22	1·7082	3·437	3·77	0·722	MEAN		
5	1·79	1·71·5	3·08	4·58	0·732	28	27 Fire Bars, ½ inch thick, in each Furnace.	
5	2·1	1·625	3·5	3·75		29	25 Fire Bars ½ inch thick, in each Furnace.	
5	2·11	1·7 „	4·0	4·25		30		
5	2·5	1·7 „	3·125	3·375		31		
8	2·23	1·725	3·54	3·792	0·727	MEAN		
7	17A	18 39	40	41	42			

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887–88.

PROCEEDINGS.

SIXTH GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, FEBRUARY 8TH, 1888.

ALEXANDER TAYLOR, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Newcastle-upon-Tyne, on January 11th, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. G. E. Macarthy and M. Sandison to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Clark, George, Jun., Southwick Engine Works, Sunderland.
Gray, George, 13, Harold Street, Sunderland.
Milburn, Christopher J., 102, Tynemouth Road, Heaton, Newcastle.
Wardale, Henry, 52, Bewick Road, Gateshead.

ASSOCIATE.

Swan, Isaac J., Grove House, Gosforth.

GRADUATE.

Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde, Manchester.

The discussion upon the paper on "The Combustion of Coal and some Evaporative Experiments with Natural and Forced Draught," by Mr. W. G. Spence, was then proceeded with; after which Mr. James Patterson read a paper on "The Results of some Experiments on an Improved Boiler Joint."

DISCUSSION ON THE COMBUSTION OF COAL AND SOME EVAPORATIVE EXPERIMENTS WITH NATURAL AND FORCED DRAUGHT.

The VICE-PRESIDENT (Mr. Alex. Taylor) expressed his regret that their President could not attend, being, in fact, in London, and Mr. Boyd, the Past-President, was also unable to be present. There was a communication from the latter, which he would call upon the Secretary to read.

The SECRETARY (Mr. Duckitt) read the following communication from Mr. Wm. Boyd, being the result of a series of experiments carried on at the Wallsend Slipway Company's Works, Wallsend, of the working of a marine boiler under natural and forced draught, from the autumn of 1886 to the summer of 1887 :—

It is not intended in this communication to go deeply into the question of the combustion of coal, or of the scientific application of forced draught, but simply to accept the invitation of the Council of this Institution to lay before the members, as an appendix to the valuable paper now under discussion, the result of a series of experiments carried on in connection with forced draught at the Wallsend Slipway for a period of about twelve months, extending from the autumn of 1886 to the summer of 1887.

It should be explained, in the first instance, that the boiler experimented upon was of the usual marine multitubular type (see Plates XXIII., XXIV., and XXV.), taken out of a vessel after having done ten years' service in the coasting trade; and it is interesting to add that, after having been worked daily for twelve months under the forced draught system, the boiler is in practically as good condition as when it was set to work about eighteen months ago, from which it would seem that the application of forced draught in a moderate way can be applied even to old boilers without giving rise to leakage or trouble.

The following are the dimensions of the boiler:—

Diameter	10 ft. 0 in. mean.
Length	9 ft. 7 in.
Two furnaces...	3 ft. 0 in. inside diameter.

HEATING SURFACE.

Tubes	793 sq. ft.
Combustion chamber ...	86 „
Furnaces	74 „
Tube plates	38 „
Total	991 sq. ft.

The tubes are 3¼ in. outside diameter, and 6 ft. 10 in. long between the tube plates, having a sectional area of 6·06 sq. ft.

The fire bars are of the ordinary type.

In the case of natural draught the fire bars were 5 ft. 2 in. long, with a total grate area of 30·8 sq. ft.

In the case of forced draught the fire bars were bricked up to 3 ft. 6 in. long, with a total grate area of 18·57 sq. ft.

The total air space area between the bars with natural draught was 1,475 sq. in., and with forced draught 1,050 sq. in.

The diameter of the chimney is 30 in. by 34 ft. high from the grate bars.

Working pressure 65 lbs. per sq. in.

The boiler is fitted with the usual type of smoke box, chimney, and furnace gear, and is employed to supply steam to an engine which drives a portion of the machinery of the engine shops, and also supplies the steam to a small steam hammer in the blacksmith's shop.

Before we started with the experiments, the results of which are given on Table 5, we ascertained by careful experiments, lasting for eighteen days, and with the boiler under *natural draught*, the actual amount of work that was required from it, and which was found to represent 3,742 lbs. of water per hour from a feed temperature of 150 degs., and with a working pressure of 65 lbs., equivalent to 4,086 lbs. of water per hour from and at 212 degs.

Having thus obtained an accurate measurement of the demands upon the boiler upon which we were about to experiment, it was our object in the various modifications of the forced draught arrangement, which we subsequently tried, to keep the pounds of water evaporated per hour by the boiler as nearly uniform as possible. How far we were successful in that is shown on the following Table :—

TABLE 5.

Conditions of Trial.	Duration of Trial in Days.	Average Number of Hours per Day.	Heating Surface.	Grate Surface in Square Feet.	Working Pressure, Lbs. per Square Inch.	Coals. Total Number of Lbs. Burnt.	Coals. Number of Lbs. per Hour.	Coals. Lbs. of Coal per Square Foot of Grate Surface per Hour.	Percentage of Ash.	Lbs. of Coal per Square Foot of Heating Surface per Hour.	Water Evaporated. From 150 degs. Feed Temperature to Boiler Pressure. Total Number of Lbs. Evaporated.	Water Evaporated. From 150 degs. Feed Temperature to Boiler Pressure. Number of Lbs. per Hour.	Water Evaporated. From 150 degs. Feed Temperature to Boiler Pressure. Number of Lbs. per Lb. of Coal.	Water Evaporated. From and at 212 degs. Number of Lbs. per Hour.	Water Evaporated. From and at 212 degs. Lbs. per Square Foot of Grate Surface per Hour.	Water Evaporated. From and at 212 degs. Number of Lbs. per Lb. of Coal.	Water Evaporated. From and at 212 degs. Lbs. per Foot of Heating Surface per Hour.	Mean Temperature in Funnel.	Area of Openings through Grate in Square Inches.	Ratio of Grate Openings to Total Grate Surface.	Temperature of Air entering Ashpits.	Lbs. of Air per Lb. of Coal.	Air Pressure near Fan.	Air Pressure, Boiler Front.	Air Pressure in Ashpit.
1	18	9·61	991	30·8	65	6,019	626	20·32	25	·632	36,031	3,742	5·9	4,086	132·7	6·43	4·12	Not taken.	1,475	$\frac{1}{3}$	55					
	7	9·14	991	30·8	65	3,708	405	13·14	15	·408	32,830	3,591	8·85	3,914	127·08	9·64	3·93	880°	1,475							
2	12	9·58	991	18·57	65	6,232	650	35·0	20	·655	39,676	4,141	6·364	4,513	243·0	6·93	4·55	970°	1,050	$\frac{1}{2·54}$	55	19·4	4¼	3½	$\frac{5}{8}$	
	7	8·85	991	18·57	65	3,136	448	24·12	15	·452	32,376	3,658	9·04	3,987	214·6	9·85	4·02	770°	1,050			26·68					
3	13	9·26	991	18·57	65	5,805	626	33·71	21	·631	36,843	3,978	6·34	4,336	233·5	6·91	4·37	870°	1,050	$\frac{1}{2·54}$	55	20·5	4¼	3¼	$\frac{3}{4}$	
	7	9·57	991	18·57	65	3,832	400	21·54	15	·423	35,021	3,659	9·13	3,988	214·7	9·95	4·02	770°	1,050			26·95					
4	8	9·62	991	18·57	65	5,526	574	30·91	20	·579	36,729	3,818	6·64	4,161·56	224·0	7·23	4·3	710°	1,050	$\frac{1}{2·54}$	135	22·3	4¼	3¼	$\frac{3}{4}$	$\frac{1}{2}$
	6	9·49	991	18·57	65	3,964	417	22·45	15	·423	35,469	3,737	8·94	4,073	219·3	9·74	4·11	750°	1,050			25·85					

The experiments which we carried out were as follows:—

1.—With the boiler under natural draught. (Plate XXIII.)

2.—The boiler under forced draught, with cold air below the grate bars only. (Plate XXIV.)

3.—The boiler under forced draught, with cold air above and below the bars. (Plate XXIV.)

4.—The boiler under forced draught, with heated air above and below the bars. (Plate XXV.)

The results of these various experiments are shown on Tables Nos. 5 and 6, the general conclusion to be drawn from which will be alluded to later on; but this seems to be the proper moment to introduce some further remarks on the conditions under which the trials were made.

The fan was one made by Gunther, 30 in. diameter, with an outlet 13½ in. diameter, driven by belts and counter-shafts off the main shop shafting; and, during the experiments, ran at 1,140 revolutions per minute.

In the hot air experiments the air was heated by passing it through the *inside* of a number of tubes which were arranged in a nest at the root of the chimney, the waste gases passing round the outside of them.

The total surface of the tubes exposed to the waste gases was 1,105 sq. ft.

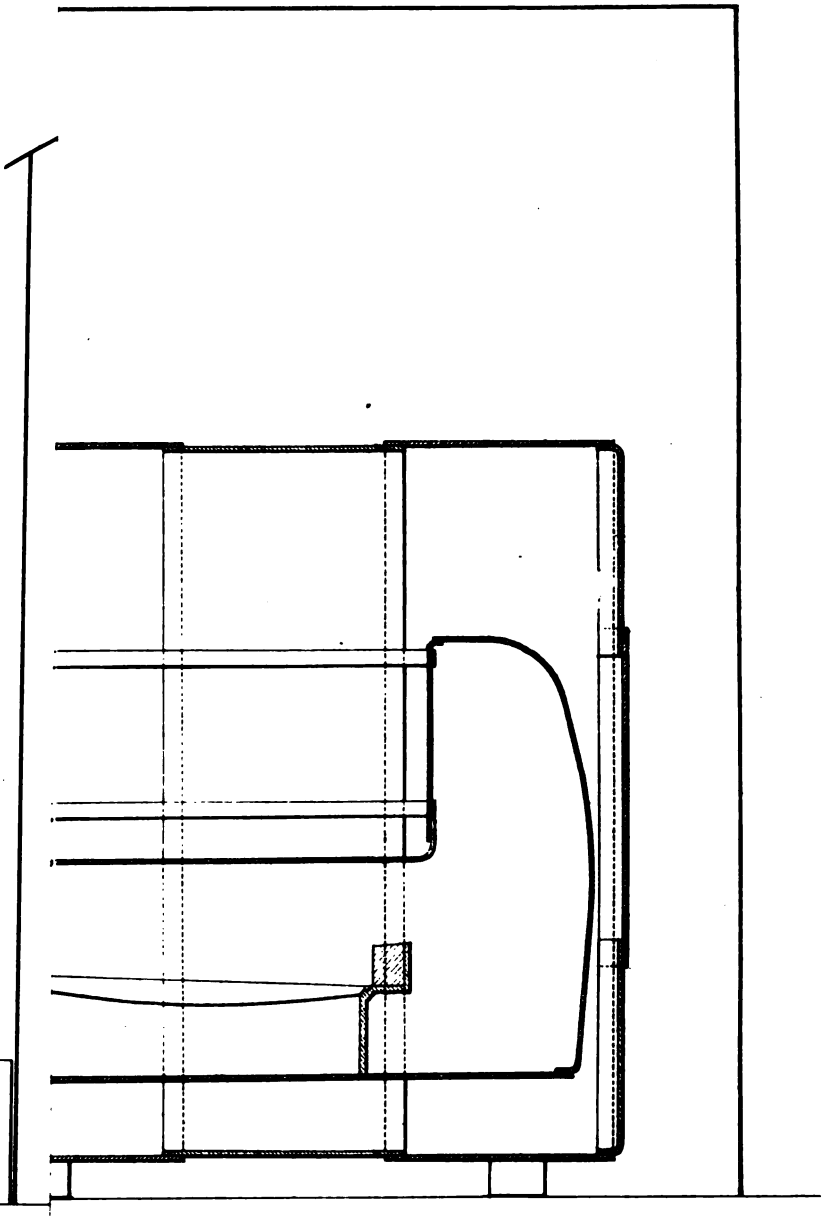
The temperature of the air on entering the heating chamber was 55 degs., and on leaving it 155 degs., but in passing down the air boxes at the sides of the boiler, where it was exposed to the atmosphere, to the boxes in front of the ashpit, the air lost about 20 degs. of heat, thus making the temperature of the air entering the ashpits about 135 degs.

The chimney temperature is found on the Table, and was taken in each case by one of Siemens' pyrometers, and the anemometer by which the quantity of air passing into the furnace was measured, was supplied by Mr. T. B. Winter, of Grey Street, and was certified for by the Hydrographical Department.

Two qualities of coal were used during the experiments, as will be seen by the Table. They are both local North Country coal. The names of each need not be specified; one had about 20 per cent. of ash, and the other 15 per cent.

Coming now to the results of these experiments, these will be found on Table 6, which will explain itself.

It will be observed that owing to the construction and design of the boiler in which these experiments were made being of a very different character from that with which Mr. Spence's experiments were



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Ant. Reid. Lith. Newcastle.

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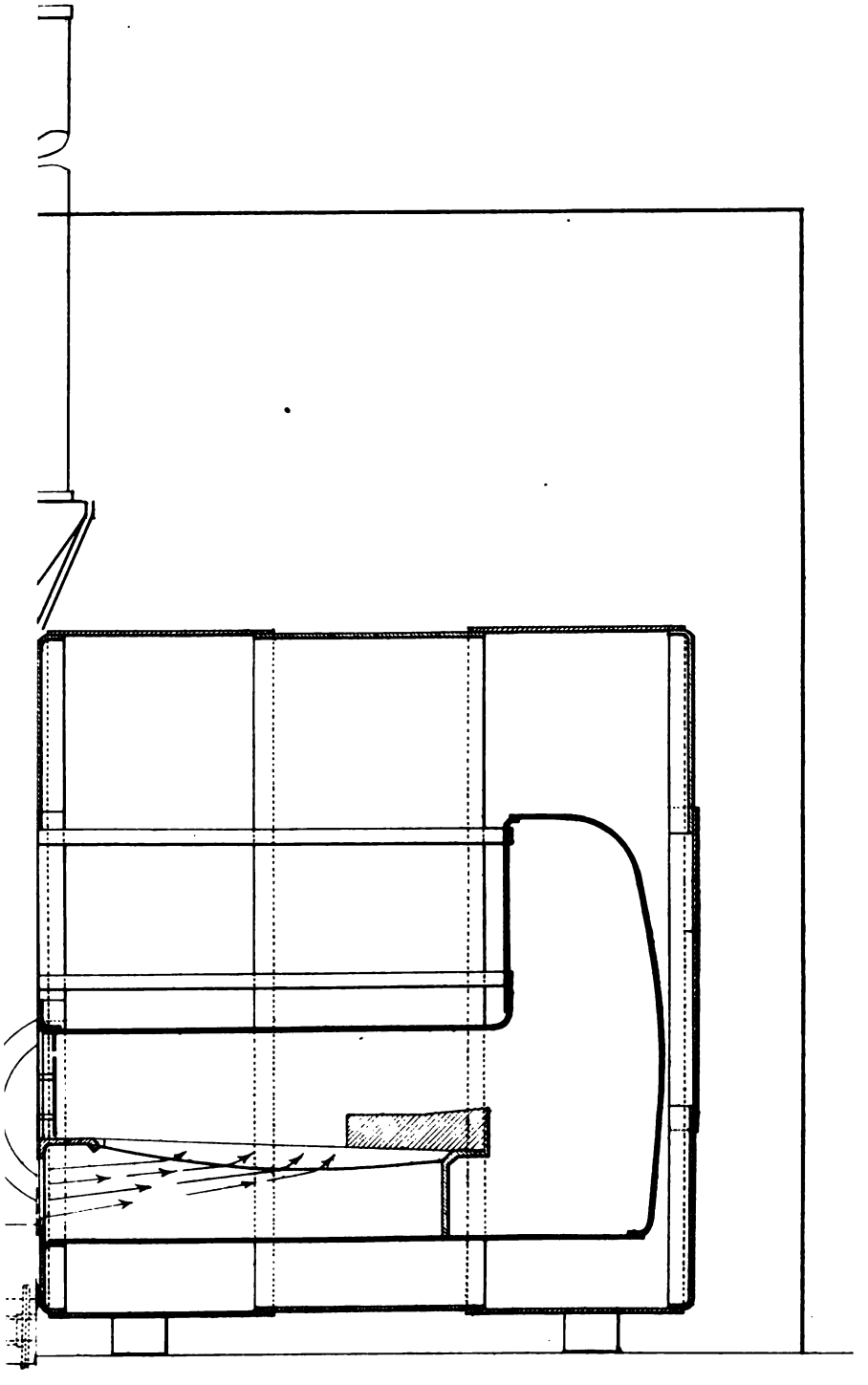

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the fire grate, and the other to consume them in the combustion chamber, care being of course taken not to admit more air into either current than is absolutely necessary for the complete combustion of the constituents of the fuel used.

The subject is one to which the writer and his staff have given very considerable attention, and have had numerous opportunities of ascertaining the results of various experiments that have from time to time been tried in the mercantile marine, to say nothing of the lengthened experiments which are referred to in the tables now submitted; and the conclusion that is forced upon us is, that up to the present time the arrangement that has the best chance of success is one that combines absolute simplicity with inexpensive adaptation, viz., the admission of the bulk of cold air under the fire bars into closed ashpits, with means provided for admitting also lesser currents of air on to the top of the bars and at the back bridges.

From a theoretical point of view there is no doubt some saving to be effected by utilising the heat of the waste gases, and this system is doubtless very attractive when first considered, but from such experience as has hitherto been obtained it would seem doubtful whether in practice there is any economical results to be obtained to compensate for the extra complication, and the introduction of fittings which must from time to time deteriorate by ordinary wear and tear.

On the other hand, by the introduction of a well constructed and economical engine and blower, combined with a low pressure in the ashpit (certainly not exceeding an average of five-eighths of an inch), economical results may, we think, be obtained.

These economies are dividable under three heads:—

First and principally.—Having facilities at hand to enable the engineer to maintain the maximum boiler pressure, and consequent revolutions and speed of ships throughout the voyage in spite of insufficient draught due to calm weather, and the interruptions due to the cleaning of fires and tubes.

There are also two other conditions of less frequent occurrence where doubtless a reliable system of forced draught would be advantageous.

Second.—When inferior and cheaper coal has to be burnt.

Third.—When, as in the case of light machinery, a reduction in the size and weight of boilers becomes of very great importance.

Mr. W. WHYTE said, the paper was a most interesting one, and Mr. Spence deserved credit for his effort to elucidate some reliable data,

besides furnishing us with much useful information as to the general principles of combustion in relation to this most important subject, viz., the best method of coal consumption in steam boilers, especially with mechanical pressure of air, his principal aim being to determine, with the same boiler and as nearly as possible under the same conditions, the per cent. of gain by the use of forced draught over natural draught. Time would not allow him (Mr. Whyte) to go into all the details of Mr. Spence's various trials, but he made out "that if a system of forced draught giving similar results to those in trials Nos. 3 and 4 in Table 3, were fitted to a natural draught boiler under the best conditions, the percentage of gain for cold air would be 4·1, and for heated air 4·78; but if the same system was fitted to a natural draught boiler under the worst conditions, there would be a clear gain of about 16 per cent. in favour of cold air, and 17 per cent. in favour of heated air, the heated air entering the furnace at 261 degrees." Now, he considered this to be a very modest gain for an experimental boiler. In summing up the whole paper, it established the conclusion at which he had arrived (after considerable experience) that the present type of marine multitubular boiler was not in any way adapted for the economical consumption of coal under forced draught either with cold or heated air. Before mentioning in what way it was unsuitable, he should for a moment draw attention to Mr. Spence's experimental boiler. He considered Mr. Spence had selected a very favourable boiler for getting the best results from his forced draught trials; it had a large roomy combustion chamber, and all the heating surface was horizontal; besides, he had his heating apparatus separate, and those who were acquainted with the construction and working of the ordinary marine boiler would, he was sure, bear him out when he said, to put it mildly, it was at least from 5 to 6 per cent. better. Further, the boiler was working on land, and not rolling about at sea. The same steady, intelligent fireman was employed throughout all the trials, who fired continuously and evenly, and kept his fires level and at an uniform thickness, whilst the tubes and grates were cleaned before every trial; good, clean coal (Stella nuts), with little or no ash, was used; Mr. Spence constantly controlling everything, especially the proper admission and diffusion of air above and below the grate. Compare all this with the usual practice in a merchant ocean tramp, and he thought the gentlemen present would agree with him that at the termination of a voyage of 20 days' continuous steaming there would not be much of Mr. Spence's 16 per cent. remaining. He was shown an experimental boiler in Scotland, about two years ago, fitted with a forced draught apparatus,

not, in his opinion, nearly so good a boiler in construction as this one of Mr. Spence's, either for grate or heating surface. He witnessed no trials himself, but was informed that from 11 to 12 lbs. of water at 212 degs. could be evaporated from 1 lb. of ordinary Scotch coal, at a rate of combustion of from 30 to 40 lbs. per square foot of grate per hour, and this could be easily done in boilers at sea; besides, about 400 degs. of heat could be returned to the furnaces from the escaping gases. Remembering at the same time that only about 50 per cent. of the heating power of coal is utilised in the ordinary boiler, the remainder being lost through imperfect combustion, radiation, and other causes, it was to him quite a revelation. Then, again, the supposed simplicity of the fan arrangement —no trouble about that—only keep it working regularly and smoothly, with a water pressure of 3 inches, and $1\frac{1}{2}$ inches in the air-casing, 1 inch in the furnace, and $\frac{1}{2}$ inch in the ashpit; valves fitted on the fronts, to open and shut as required, so as to balance the pressure above and below the grate to an atom; taking care to supply the engineers and firemen with a barometer, thermometer, anemometer, and pyrometer, and then you are complete! Forty per cent. saving in coal, and, as a natural consequence, dividends all round. He had had a good deal to do in testing this on a larger and more practical way, and he might tell them that he had lost considerable confidence in that Scotch experimental boiler. Supposing you had valves to work automatically and with precision, and that there was no doubt about the regulating of the velocity, supply, or temperature of the air, still the diffusion and distribution of the air after it got inside, above and below the grate, was, to say the least of it, a very doubtful factor as to its movements afterwards either with cold or heated air. If it required for perfect combustion of coal about 2 atoms of oxygen for every atom of solid carbon, the present fixed grate bar, either longitudinal or transverse, thick or thin, space them as you like, was not suitable for getting anything like the quantity of oxygen required for perfect combustion, there being about 60 to 70 per cent. of solid iron between the oxygen and carbon—though he was convinced that a continuously moving bar would greatly overcome this—otherwise, on a rough calculation, it would at least require about 20 tons of air to each ton of coal; but with the ordinary fixed bar, and using cold air under pressure, it was possible on a short voyage for a day or two, so long as the bars and tubes were clear and clean, to get a better coal combustion with much higher evaporating results; but by-and-by, as one-third of the bars got choked up with clinker, the cold air, still rushing through at a high velocity, impinged on the

the liberty of enforcing an idea Mr. Spence had indicated at the close of his paper, viz.:—That this Institution raise a sufficient sum of money to be divided into three substantial prizes (open to the whole country) for the best design of a boiler suitable for the economical consumption of coal under mechanical pressure of air. To show how delusive experiments were sometimes, not only on land boilers but boilers practically working at sea, two steamers were built last year as near as possible on the same lines, the one fitted with forced draught apparatus for heated air and the other natural draught. The grate surface of the latter boiler was 45 square feet; the other was shortened to 36 square feet, both boilers working to 160 lbs. The natural draught boiler consumed about 10 tons per day. On the first voyage of the vessel with the forced draught boiler the revolutions of the fan were about 600, average water pressure at fan $2\frac{1}{2}$ inches, air casing $1\frac{1}{2}$ inches, furnace $\frac{4}{10}$ inch, ashpit $\frac{1}{10}$ inch. This was supposed to be about the correct thing, according to experiment—consumption of coal at the end of the voyage, 10 tons 11 cwts., cleaning nine fires during the 24 hours, and not able to keep steam, which was as follows:—150 lbs., 140 lbs., 158 lbs., and the last few days 138 lbs. Afterwards the grate surface was increased to 45 square feet, the fan revolutions reduced nearly one-half, the pressure to about 1·3 inch, casing ·35 inch, furnace ·1, and in ashpit $\frac{1}{10}$ inch, the supposed result being —consumption, 8·3 tons per day, which was considered satisfactory, but subsequent voyages have failed to maintain this gain, the explanation of which is given thus. "After all improvements and extra care for one trip she seemed to come down to 8·3 tons, but the conclusion is that there must have been some mistake, as on the next and following voyages the consumption rose to $10\frac{1}{2}$ tons per day, which is about the same as the natural draught vessel. The supposed improvement was obtained by lengthening the fire bars to the length of the other vessel and reducing the speed of the fan, also reducing the pressure under the fire bars to $\frac{1}{10}$ of an inch water pressure." There may be some other system or modification than that which he had to do with working successfully and economically in the present type of marine boiler; it there was he was ignorant of it, but he simply gave them his own practical experience, and sometimes in matters of this kind one atom of practice was worth ten of theory. He begged to thank Mr. Spence for his valuable paper.

Mr. J. C. JOBLING said, that in discussing Mr. Spence's paper he thought the most important part they had to consider was the admission of air, not only as to the quantity, but as to the mode of putting it into the furnace. There were a great many different ideas on this point in

altogether. It had been said that thin bars would burn through, and that a large section was required to stand the heat of a furnace; but it was the very opposite; for as they all knew fire bars were kept cool by the passage of air between them; thus, the lighter the section, the easier to keep cool by the passing air. They never saw clinker adhering to thin bars in the way it did on thick bars, and this was owing to their coolness. He had some particulars gathered from five steamers, taking the results of one year's work under natural draught when using best coal, and afterwards forced draught and using small or duff coal. He might say that he had come to the conclusion that the only saving to be got from forced draught was by burning coal at half the price of best coal, of course doing the same work with the cheap coal. The small appreciable saving they had with forced draught when burning best coal did not at the end of a voyage bear out the 15 and 16 per cent. found in the trials; but if they could get a saving of 40 and 50 per cent. by using cheap coal, and carrying no more of it, and in many cases less, why use best coal? The data (see Table 7) from five steamers for one whole year's working came out at the end of that time as a saving of 10 per cent. in weight and 50 per cent. in price; that is, these steamers had used 10 per cent. less of cheap coal in one year than they did of coal costing double the price. In the system used the ratio of heating surface to 1 lb. of coal had been as low as 1·5 and as high as 2·2 with natural draught, and the proportion of heating surface to grate surface had risen from 29·5 to 48·5, or an average of about 32 per cent. reduction on the grate surface. In one part of the

TABLE 7.

Steamer's Name.	Consumption per Day, in Tons.		Proportion of Heating Surface to Grate Area.		Coals Burnt per Square Foot of Grate.		Indicated Horse-Power.	Consumption per I.H.P.		Dead-weight.	Working Pressure.	Grate Area.			Reduction in Square Feet of Grate Area with Forced Draught.	Water Pressure.
	Natural Draught, burning Best Coal.	Forced Draught, burning Duff Coal.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.		Natural Draught.	Forced Draught.			Natural Draught.	Forced Draught.	Heating Surface.		
Odiel ...	11·5	10·5	25·1	47·4	15·6	24·0	560	1·9	1·70	1,650	80	68·75	36·0	1708·7	32·75	⅛ in
Calanas ...	14·0	12·5	34·6	50·4	18·1	24·5	680	1·94	1·72	2,050	80	72·0	49·8	2495·0	22·2	⅛ „
Palomares	13·0	12·5	31·7	43·6	18·3	24·4	630	1·92	1·85	1,800	80	66·0	48·0	2094·0	18·0	⅛ „
Mentana..	14·5	13·0	33·0	49·2	17·0	25·0	715	1·89	1·7	2,250	90	80·0	54·0	2658·0	26·0	⅛ „
Linares ...	15·0	13·0	33·3	49·4	17·5	26·0	710	1·97	1·71	2,250	80	80·0	54·0	2668·0	26·0	⅛ „

conducted, the evaporative results are of course very inferior, and are indeed not comparable the one with the other.

TABLE 6.

Conditions of Trial.	Lbs. of Water Evaporated from and at 212 degs. per Lb. of Coal.	Percentage of Economy.	Lbs. of Water Evaporated from and at 212 degs. per Square Foot of Grate.	Percentage of Increase.	Lbs. of Water Evaporated from and at 212 degs. per Square Foot of Heating Surface.	Percentage of Increase.	Lbs. of Coal Burnt per Square Foot of Grate Area per Hour.	Percentage of Increase.
1	6·43	0	132·7	0	4·12	0	20·32	0
	9·64		127·08		3·93		13·14	
2	6·93	7·77	243·05	83·14	4·55	10·43	35	72·24
	9·85	2·17	214·62	68·7	4·02	2·3	24·12	83·5
3	6·91	7·46	233·48	75·93	4·37	6·06	33·71	65·89
	9·95	3·21	214·76	68·8	4·02	2·3	21·54	63·9
4	7·23	12·44	224·09	68·86	4·3	4·37	30·91	52·16
	9·74	1·0	219·34	72·6	4·11	4·58	22·4	70·4

It will, however, be noticed that when the effect of forced draught is in each case referred to the common basis of the results obtained with natural draught, the economical results in these series of experiments may be said generally to confirm those arrived at by Mr. Spence; and we venture to submit that the broad conclusions to which they point are as follows:—

That in the adoption of any system of forced draught in the mercantile marine, it is absolutely essential that if any degree of success is to be obtained, the utmost simplicity of mechanical arrangements must be strictly adhered to.

To our minds the problem which to-day has to be solved is, how to make coals of any given quality produce their maximum effect by the use of the simplest and cheapest mechanical appliances.

There is but one way to accomplish this, viz., by an artificial blast, provided with mechanical means for dividing the volume of air required for combustion into two separate currents, the one to create the gases in

stated the quantity of air which was absolutely essential for the combustion of gases when admitted above the fire, and had also shown the relative effect of low or insufficient supply. By admitting the air in proper quantities this steam boiler was increased in power 10 per cent. under natural draught. With regard to the question whether there was any advantage, he might say they really started these experiments with the view of ascertaining the efficiency of forced draught as against natural draught, and hot forced draught as against cold forced draught. He thought they had clearly proved by these experiments, partial as they were, that the gain by heating the air was extremely small, something like 0·6 per cent. That he respectfully submitted to his friend, Mr. Howden, to whom he need not say they owed so much in this connection, that in common parlance, "the game was not worth the candle." In order to obtain any sensible increase in temperature, such a large amount of appliances and fittings were necessary, and these appliances under conditions in which they must deteriorate rapidly, that the saving would never compensate for the vast amount of trouble involved in fitting up and wear and tear. With regard to the advantage of artificial draught generally, what they had been all along anxious to ascertain, was, is artificial draught economical, or is it as economical as the natural draught? Could a boiler be fitted with forced draught arrangements, which had other collateral advantages, and work it as economically as they could natural draught? He thought these experiments conclusively proved that forced draught could be worked as economically. That was the result of these experiments, but he maintained further that had these experiments been carried out to a greater extent they would have found increased efficiency by extended experiments. Unfortunately that was not possible, as Mr. Spence had accepted an appointment and transferred his very valuable services to a more responsible position in another important establishment in the city, but he (Mr. Marshall) sincerely trusted the coal trade in this district would take up the question. He saw some of the members present and hoped steps would be taken by the representatives of this body either independent of or in conjunction with this Institution. Seriously he trusted there would be a surplus from the Exhibition, and hoped that that surplus, arising out of a Mining and Engineering Exhibition, would be devoted to the furtherance of the Northumberland coal trade, by proving in forced draught work Northumberland coal could be as smokeless and efficient as Welsh coal. He thought the advice and the experiments as pointed out by Mr. Spence, would raise

besides furnishing us with much useful information as to the general principles of combustion in relation to this most important subject, viz., the best method of coal consumption in steam boilers, especially with mechanical pressure of air, his principal aim being to determine, with the same boiler and as nearly as possible under the same conditions, the per cent. of gain by the use of forced draught over natural draught. Time would not allow him (Mr. Whyte) to go into all the details of Mr. Spence's various trials, but he made out "that if a system of forced draught giving similar results to those in trials Nos. 3 and 4 in Table 3, were fitted to a natural draught boiler under the best conditions, the percentage of gain for cold air would be 4·1, and for heated air 4·78; but if the same system was fitted to a natural draught boiler under the worst conditions, there would be a clear gain of about 16 per cent. in favour of cold air, and 17 per cent. in favour of heated air, the heated air entering the furnace at 261 degrees." Now, he considered this to be a very modest gain for an experimental boiler. In summing up the whole paper, it established the conclusion at which he had arrived (after considerable experience) that the present type of marine multitubular boiler was not in any way adapted for the economical consumption of coal under forced draught either with cold or heated air. Before mentioning in what way it was unsuitable, he should for a moment draw attention to Mr. Spence's experimental boiler. He considered Mr. Spence had selected a very favourable boiler for getting the best results from his forced draught trials; it had a large roomy combustion chamber, and all the heating surface was horizontal; besides, he had his heating apparatus separate, and those who were acquainted with the construction and working of the ordinary marine boiler would, he was sure, bear him out when he said, to put it mildly, it was at least from 5 to 6 per cent. better. Further, the boiler was working on land, and not rolling about at sea. The same steady, intelligent fireman was employed throughout all the trials, who fired continuously and evenly, and kept his fires level and at an uniform thickness, whilst the tubes and grates were cleaned before every trial; good, clean coal (Stella nuts), with little or no ash, was used; Mr. Spence constantly controlling everything, especially the proper admission and diffusion of air above and below the grate. Compare all this with the usual practice in a merchant ocean tramp, and he thought the gentlemen present would agree with him that at the termination of a voyage of 20 days' continuous steaming there would not be much of Mr. Spence's 16 per cent. remaining. He was shown an experimental boiler in Scotland, about two years ago, fitted with a forced draught apparatus,

indebted to Mr. Spence in laying before this Institution the results of his experiments. Not only were such experiments in themselves of value, but the material for discussion offered that opportunity for a thorough ventilation of the subject which was always desirable. Mr. Spence had certainly described in a most practical manner the theory of combustion, and he was sure he could not quote a better authority than the late Mr. Wye Williams. Mr. Spence had strongly dwelt upon the necessity of air supply to the gases direct, which undoubtedly was of the greatest importance—the very pith of the whole question. Referring to the coal used, he said:—"The coals were always got from the same colliery, they varied but little in size or quality, and were fairly free from dirt and dust." Mr. Pattinson's analysis shows the calorimeter efficiency 14·1 lbs. of water per lb. of coal, which is much in excess of that generally supplied to the majority of steamers. The elaborate trials conducted in this neighbourhood during the years 1857-58, by the Collieries' Association and by the Admiralty, with the best qualities of North Country coal, and under the most careful conditions—using a marine boiler—gave the mean evaporative efficiency 10½ to 11 lbs. of water per lb. of coal. Taking this as a basis of comparison, Mr. Spence appeared to have obtained in trials 25 to 31, Table 1., a high efficiency, which no doubt was due in a great measure to the quality of the coal used. "Owing to the clean nature of the coal used, the quantity of clinker in the fire at the conclusion of each trial was not very great." Trials 25 to 27, in which there were 29 fire bars and all the air holes direct to the gases open, they got a mean efficiency of 10·19 lbs. of water evaporated, with an air supply of 20·39 lbs. per lb. of coal. Pass on to trial 28, the same air holes were open to the gases, two fire bars were taken out, an increased evaporative efficiency was obtained with a material reduction in the air supply, which was remarkable when they considered trial 31, wherein the highest efficiency was obtained by taking out other two fire bars, the air admission direct to the gases being the same, but the air supply had again run up to 20 lbs. per lb. of coal. Unfortunately the trials here ceased. What would have been the result if another fire bar, or say other two, had been taken out and more air admitted through the grate, say sufficient to make the total supply 24 lbs. per lb. of coal? It might even have increased the evaporative efficiency to such a point that the forced draught trials would have shown a loss. At all events the efficiency appeared to have increased with the increased air admission through the grate. Judiciously more air could not be admitted at the furnace front, and the admission of air at the

weaker parts of the fires, burning through into holes, and thereby lowering the temperature of the furnaces and combustion chambers, so, at any rate on long voyages, every advantage would be lost by unequal temperatures, and the constant cleaning and renewal of fire bars. Another weak point in construction was the smallness of the furnaces and combustion chambers. Supposing there was a perfect system of air distribution, then the fuel was burning on a very small grate surface with a high bridge; the consequence was the heat was intensified within a small compass, and diffusion of heat became confined and limited. (This also applied to cold air under pressure.) To prove this he had repeatedly tried the temperature of the escaping gases in the uptake, both under natural draught and forced draught, and found little or no difference, and he believed there was a great deal of fallacy in regard to the taking of the temperatures with any instrument he had seen used on board ship. On the supposition that the escaping gases from forced draught carried a much higher degree of heat to the uptake, and the cold air from the fan meeting them, entered the furnace at a high temperature from 300 degs. to 400 degs., he did not believe that it entered at that temperature or anything like it. He would say 150 degs. was nearer it. So that with the present construction of marine boiler almost as good a distribution of heat was obtained with natural draught as with heated forced draught; and when the wear and tear of fan and engine was taken into consideration, also keeping the heating tubes clean and free from scale, repairing of the fronts, air-tight casings, doors, valves, air boxes, and heating apparatus all more or less burning, deteriorating, and oxidising, the balance was certainly in favour of natural draught with the present marine boiler. For all this forced draught would, he thought, eventually supersede natural draught. Mr. Spence's trials went a long way to prove this. There was only one kind of boiler which occurred to him on whose lines could be based the future forced draught, and that was the Howard. He knew its defects well, especially a bad circulation of water through the tubes, along with a large deposit of sediment, but this could be overcome. The late Mr. Jordan attempted something of the kind in the S.S. "Montana," but he made his tubes too large—15 inches diameter. He riveted them rigidly at both ends, making no allowance for expansion and contraction; also both grate and heating surface were distributed badly. He had no time to point out other suitable features in this kind of boiler, but it was not requisite to carry so much dead unavailable water absorbing useful heat as was carried in the present type of marine boiler, and he would take

advantage forced draught offered for such reduction—("Owing to the more searching nature of air from a blast under pressure, a smaller surplus is required when using forced draught; and on the authority of Professor Rankine may in the case of ordinary well-constructed boiler furnaces be taken at 6 and 12 lbs. per lb. coal for forced and natural draught respectively; making, with the 12 lbs. chemically necessary, the total rate of air supply required for maximum efficiency = 18 and 24 lbs. per lb. of coal." But Professor Rankine did not stop there; he continued as follows:—"And it is possible that, by blowing the air for combustion into a furnace in small enough jets and with sufficient force, air for dilution might be rendered unnecessary." And then again he says:—"It appears further, as has already been stated, that with a forced draught there is less air required for dilution, consequently a higher temperature of the fire, consequently a more rapid conduction of heat through the heating surface, consequently a better economy of heat than there is with a chimney draught")—yet, in the face of this, they found in the forced draught trials more air supplied per lb. of coal than in the natural draught trials, and no air admitted to the gases except at the furnace front. Take trials 3 and 4, Table 3, where they had the highest evaporative efficiency per lb. of coal: the air supply was 20·3 lbs., equal to the highest supply under natural draught; and, therefore, how was it possible to have obtained a higher efficiency? In fact, he was surprised at the results obtained. Referring to trials 12 and 13, they had there the largest quantity of water evaporated in lbs. per hour, but the lowest evaporative efficiency per lb. of coal. The whole of the air holes at the furnace fronts were open, and the air was supplied at these holes under a water gauge pressure of 2·5. Then take trials 17 and 18, here they had the least air supply and the lowest ashpit pressure, and yet the evaporative efficiency was nearly equal to trials 3 and 4. In fact, when they considered the area of the holes open at the furnace front and the water gauge pressure of the air passing through those holes, and that the air practicaly converged to a common focus, judging from the position of the holes as shown in the drawing, there was no doubt the coals had been consumed at the front of the fire, very much the same as in a smith's fire. Under such conditions the calorific efficiency must have been low, even assuming part of the coals at the furnace front were consumed to carbonic acid, which gas in passing over the rest of the distilling fuel would take up another portion of carbon with the production of carbonic oxide and great loss of heat. Although Mr. Spence alluded to the funnel damper, yet, he regretted

forced draught, requiring all the light it was possible to throw upon it. He was only told the other day by the Chairman of an instance where, out of a set of boilers under trial, the boiler of greatest evaporative efficiency used 24 lbs. or 300 cubic feet of air per lb. of coal per hour; the next boiler in efficiency consumed 12 lbs. or 150 cubic feet per lb. of coal per hour. He hoped Mr. Taylor later on would tell them more about this. Mr. Spence has mentioned in one part of his paper that there was a likelihood of getting too little air over the fire. He did not quite think that was applicable to all boilers, for in one set of boilers with which Mr. Spence was connected it was quite the opposite. Mr. Spence went round from Antwerp to Cardiff to study the working of these boilers, and his statement was that the first twelve hours he could not do anything with them at all, and could only maintain steam 12 lbs. short of full pressure. He had tried all sorts of expedients without success until he closed the damper, thus preventing the excessive inrush of cold air through the perforated and ill-fitting doors, which were of the usual kind fitted for natural draught, when the steam at once commenced to rise, and rose 12 lbs. in 18 minutes; and he (Mr. Jobling) thought that the failure was due to the lowering of the temperature of the furnace by admitting too much cold air, and thus preventing the total ignition of the gases in the combustion chamber. If the furnace door of a boiler was opened on the first sneck, and the fire observed through a peephole, it would be seen that the flame fell a few inches below the furnace crown; this, of course, spoke for itself. Mr. Whyte had been very severe upon the advocates of forced draught. His (Mr. Jobling's) experience differed widely from Mr. Whyte's, whose results, he believed, were obtained from best coal. If they could evaporate the same amount of water with small coals that Mr. Whyte had done with best there must be a great difference in the systems used. In the trials dealt with in this paper Mr. Spence had given up using longitudinal bars in preference for transverse bars; and he told them the reason was he could not get the longitudinal bars low enough with the small diameter of furnace used in the trials. There was another reason of which Mr. Spence had not told them. He (Mr. Jobling) thought with forced draught they required to split the air up in as many *laminæ* or streaks as possible. If they had the bars widely pitched and longitudinal, the air would enter the fire in thick streams, leaving the space immediately above the bars doing no work compared with the space between the bars, which was receiving the greater amount of air. Many failures in forced draught were due to the warping and twisting of the fire bars, and in some cases the bars have been known to come down

would require to be very efficient and of small first cost and upkeep." He was most fully of the same opinion. There could be no question every unit of heat obtained from the waste gases and returned to the furnace was a unit of heat gained but nothing more. He felt assured the cost of fitting any apparatus for such purpose to a marine boiler would much exceed the value so gained. In conclusion he might just refer to Mr. Spence's closing suggestion that the above results "point to the desirability of having a series of reliable public trials, conducted by an engineer of recognised reputation and ability * * * Say two similar type boilers were tried, one fitted up as best suited for natural draught, and the other designed expressly for forced draught, and let them both be steamed for say twelve hours per day for ten days." He must confess he did not see the practical utility of such trials. If any trials were to be carried out with a view to real practical advantage, those trials must be carried out on board a steamer in the execution of a voyage, and he was satisfied from his own experience with forced draught, which extended over some four years, the advantages gained much exceeded any natural draught results he ever had been able to obtain, and this more particularly so in the Indian trade. He should have liked to have put before this meeting data obtained from the various forced draught steamers which they have in the Indian and Mediterranean trades, but he feared he had already exceeded the time allowed for discussion, and, therefore, at some future date, if agreeable to this Institution, he should have pleasure in doing so. He again wished to repeat, relative to the proposed trials in boilers, that he held no trials would be of practical value unless made on board a steamer at sea in the execution of a voyage.

Mr. Wm. H. Scott said, he thought he should be the last man to say a word on this subject when he came in, "but who shall decide when doctors disagree?" He had had experiments on board ship. His firm had proved conclusively the advantage of the forced draught with small or duff coal as compared with the ordinary draught and the best coal. If Mr. Whyte and Mr. Fothergill desired that experiments should be made, he would be very happy to give them a free passage by one of their converted boats (the "Ferrando," that had been fitted with forced draught) for the purpose. They would put into the boat for the full voyage out and home the best steam coals instead of the duff, and he should undertake to say that the consumption of the Ryhope screened best coal would be very much less than the consumption with the ordinary draught, to the extent of 15 to 20 per cent. Since this system of forced draught had been fitted the consumption of duff had been less than with best

paper it was stated that after substituting transverse thin bars for longitudinal ones the percentage over natural draught immediately rose 2·6 at once, showing the effect of splitting up the air into as many parts as possible. The data he gave were brief but correct, as they were taken from actual voyages of ordinary working steamers. He was connected with a steamer now building in which they had somewhat modified the boiler for forced draught, and hoped to have better results, as the whole success depended on the admission of air and the flow or speed of the gases in the furnace and tubes.

Mr. F. C. MARSHALL said that his name having been mentioned at the beginning of the paper, he thought it only fitting to make some explanation in reference to the data, and the means which Mr. Spence had placed at his disposal for carrying out these experiments. He would quite endorse what Mr. Whyte said, that the greatest credit was due to their friend, Mr. Spence, for this, as for many other services in connection with this Institution; for the very satisfactory and very complete way in which these experiments had been recorded, and the care with which he had got up the paper. It was at his (Mr. Marshall's) suggestion, as Mr. Spence had said, that these experiments were made, not with the intention of recording them in the form of a paper on the subject; but afterwards, when he observed the development of the subject in Mr. Spence's hands, he suggested to him to prepare this paper. He did not agree with Mr. Whyte that the boilers placed at Mr. Spence's disposal were the best for carrying out these experiments, 2 feet 3 inches was a very insufficient size for a furnace in which to carry on the combustion of coal, as was fully proved by the fact that when the bars were lowered by five inches, and increased capacity given above the fire, a very large increase of efficiency was obtained, showing that much more room was wanted above the grate bars for the combination of the gases with the air supply. Two or three things had come out in this paper which he thought very valuable. The first was, they were brought back something like forty years in the management of their furnaces. It was nearly forty years since they were told by Lord Armstrong (then Mr. W. G. Armstrong), Mr. Longridge, and other members of the committee appointed by the Coal Trade of Northumberland, that the essential to burn North Country coal was to have air admitted above the furnace. In practice that had been almost entirely forgotten. Where they would find one marine boiler fitted up with appliances to supply air over the grates, they would find 500 without any provision to supply air over the grates, or, if fitted, in such small quantity as to be almost useless. Mr. Spence had

stated the quantity of air which was absolutely essential for the combustion of gases when admitted above the fire, and had also shown the relative effect of low or insufficient supply. By admitting the air in proper quantities this steam boiler was increased in power 10 per cent. under natural draught. With regard to the question whether there was any advantage, he might say they really started these experiments with the view of ascertaining the efficiency of forced draught as against natural draught, and hot forced draught as against cold forced draught. He thought they had clearly proved by these experiments, partial as they were, that the gain by heating the air was extremely small, something like 0·6 per cent. That he respectfully submitted to his friend, Mr. Howden, to whom he need not say they owed so much in this connection, that in common parlance, "the game was not worth the candle." In order to obtain any sensible increase in temperature, such a large amount of appliances and fittings were necessary, and these appliances under conditions in which they must deteriorate rapidly, that the saving would never compensate for the vast amount of trouble involved in fitting up and wear and tear. With regard to the advantage of artificial draught generally, what they had been all along anxious to ascertain, was, is artificial draught economical, or is it as economical as the natural draught? Could a boiler be fitted with forced draught arrangements, which had other collateral advantages, and work it as economically as they could natural draught? He thought these experiments conclusively proved that forced draught could be worked as economically. That was the result of these experiments, but he maintained further that had these experiments been carried out to a greater extent they would have found increased efficiency by extended experiments. Unfortunately that was not possible, as Mr. Spence had accepted an appointment and transferred his very valuable services to a more responsible position in another important establishment in the city, but he (Mr. Marshall) sincerely trusted the coal trade in this district would take up the question. He saw some of the members present and hoped steps would be taken by the representatives of this body either independent of or in conjunction with this Institution. Seriously he trusted there would be a surplus from the Exhibition, and hoped that that surplus, arising out of a Mining and Engineering Exhibition, would be devoted to the furtherance of the Northumberland coal trade, by proving in forced draught work Northumberland coal could be as smokeless and efficient as Welsh coal. He thought the advice and the experiments as pointed out by Mr. Spence, would raise

the character of the Northumberland coal. There was just one point on which he wished to say a word, with reference to the fitting of those bars to which Mr. Jobling alluded. He (Mr. Marshall) quite agreed with the principle of the furnace bars being placed transversely in the furnace as a very advantageous one in the case of the application of forced draught. The mere resistance to the air passing up through was compensated for by the advantage of the air being divided into very thin laminæ, and being passed through the fuel and into the furnace in a direction at right angles to the direction of the current, so the gases would thus be more thoroughly mixed than they otherwise might be. He might add it had been his intention if Mr. Spence had remained with them to have doubled the length of the furnace and then to have ascertained what was the relative efficiency between the increased furnace burning the same kind of fuel—that is, having the same heating or absorbing surface—in the same boiler. That they had yet to prove, and one of the very important questions that remained to be solved. It was quite clear they would have a much greater intensity of heat in the furnace, and a much larger proportion of the heat would pass through the plates into the furnace and thus secure as efficient combustion of fuel with the fuller as with the shorter grates. When they commenced the forced draught some years ago 3½ and 4 lbs. of coal per horse-power was what they burnt. Now, 2½ lbs. were consumed under 4-inch pressure, and that was largely due to the air passing through fuel. He could not share in his friend Mr. Whyte's views with reference to the application of forced draught. He (Mr. Marshall) was quite sure the time would come when no steamer would be without forced draught. Air-induced draught in the funnel had been applied without success owing to the much larger volume of vapour—double the amount—to move. In the locomotive this was done, but in such application they had the advantage of the exhaust steam doing the work. He thought the diagrams of Mr. Spence important as showing the serious decrease of temperature caused by opening and shutting the fire doors. It was a strong indication that something in the direction of a mechanical feeder was required for all boilers, but in no case to his knowledge had such appliances been satisfactory on board ship, but the variations indicated, amounting to something like 200 degs. in the smoke box, must be detrimental to the efficient working of the boiler.

Mr. J. R. FOTHERGILL, the next speaker, said:—As there was much controversy and doubt amongst engineers and shipowners relative to the question of forced draught, he could but repeat that they were greatly

indebted to Mr. Spence in laying before this Institution the results of his experiments. Not only were such experiments in themselves of value, but the material for discussion offered that opportunity for a thorough ventilation of the subject which was always desirable. Mr. Spence had certainly described in a most practical manner the theory of combustion, and he was sure he could not quote a better authority than the late Mr. Wye Williams. Mr. Spence had strongly dwelt upon the necessity of air supply to the gases direct, which undoubtedly was of the greatest importance—the very pith of the whole question. Referring to the coal used, he said:—"The coals were always got from the same colliery, they varied but little in size or quality, and were fairly free from dirt and dust." Mr. Pattinson's analysis shows the calorimeter efficiency 14·1 lbs. of water per lb. of coal, which is much in excess of that generally supplied to the majority of steamers. The elaborate trials conducted in this neighbourhood during the years 1857-58, by the Collieries' Association and by the Admiralty, with the best qualities of North Country coal, and under the most careful conditions—using a marine boiler—gave the mean evaporative efficiency 10½ to 11 lbs. of water per lb. of coal. Taking this as a basis of comparison, Mr. Spence appeared to have obtained in trials 25 to 31, Table 1., a high efficiency, which no doubt was due in a great measure to the quality of the coal used. "Owing to the clean nature of the coal used, the quantity of clinker in the fire at the conclusion of each trial was not very great." Trials 25 to 27, in which there were 29 fire bars and all the air holes direct to the gases open, they got a mean efficiency of 10·19 lbs. of water evaporated, with an air supply of 20·39 lbs. per lb. of coal. Pass on to trial 28, the same air holes were open to the gases, two fire bars were taken out, an increased evaporative efficiency was obtained with a material reduction in the air supply, which was remarkable when they considered trial 31, wherein the highest efficiency was obtained by taking out other two fire bars, the air admission direct to the gases being the same, but the air supply had again run up to 20 lbs. per lb. of coal. Unfortunately the trials here ceased. What would have been the result if another fire bar, or say other two, had been taken out and more air admitted through the grate, say sufficient to make the total supply 24 lbs. per lb. of coal? It might even have increased the evaporative efficiency to such a point that the forced draught trials would have shown a loss. At all events the efficiency appeared to have increased with the increased air admission through the grate. Judiciously more air could not be admitted at the furnace front, and the admission of air at the

bridge B practically would not answer, which Mr. Spence admitted in his statement that the "method had the disadvantage that the holes could be very easily covered over by any slag or clinker which might find its way to and remain lying on the top of the bridge." Thus, he must confess, he failed to see how in general practice Mr. Spence on his own showing was going to supply the quantity of air to the gases direct, necessary for complete combustion; and this problem was much more difficult in the multitubular marine boiler under the general conditions required for sea use under natural draught, and therefore he felt the high evaporative efficiency obtained by Mr. Spence did not offer a fair basis of comparison, for it was obtained under exceptional conditions which could not be carried out in daily practice at sea. Take a steamer making a passage of 10, 20, or 30 days. Coals certainly not free from dirt or dust, fires to clean every four hours with loss of steam, tubes dirty, fire bars burnt on the surface and twisted, furnace front baffles burnt into holes, air admission seriously interfered with, to say nothing about the extraordinary views often entertained by the men relative to firing, and thus they had very different conditions to those in which the results in Table 1 were obtained. He was of the opinion the generality of marine boilers throughout a voyage did not give a higher efficiency than 8 to 8½ lbs. of water per lb. of coal. Mr. Spence's contention appeared to be there was little or no practical value in forced draught, for if proper care was taken as to the quantity of air supplied, and how and where it was admitted, the results under such conditions by natural draught would preclude the use of forced draught. In theory, or under the conditions of special test trials with clean fires and tubes, etc., and only of some six hours' duration, he fully agreed with him, but in general practice under such conditions as will meet the requirements incidental to continuous steaming at sea, he contended the air could not be so admitted by natural draught as to produce those results which Mr. Spence anticipated. With forced draught the air could be delivered and directed with great efficiency and under conditions most favourable to combustion, and in addition to this important advantage, there are many other features, some of which Mr. Spence has referred to in the last page of his paper. Relative to the forced draught tables, Mr. Spence said, "From the results of the ten trials given in Table 2 it was concluded that no satisfactory results could be obtained in these furnaces or grates, as shown in Plate XIII." And thus he would pass on to Table 3. It seemed somewhat remarkable that though Mr. Spence so emphatically pointed out the saving derived by reducing the air supply, and the

advantage forced draught offered for such reduction—("Owing to the more searching nature of air from a blast under pressure, a smaller surplus is required when using forced draught; and on the authority of Professor Rankine may in the case of ordinary well-constructed boiler furnaces be taken at 6 and 12 lbs. per lb. coal for forced and natural draught respectively; making, with the 12 lbs. chemically necessary, the total rate of air supply required for maximum efficiency = 18 and 24 lbs. per lb. of coal." But Professor Rankine did not stop there; he continued as follows:—"And it is possible that, by blowing the air for combustion into a furnace in small enough jets and with sufficient force, air for dilution might be rendered unnecessary." And then again he says:—"It appears further, as has already been stated, that with a forced draught there is less air required for dilution, consequently a higher temperature of the fire, consequently a more rapid conduction of heat through the heating surface, consequently a better economy of heat than there is with a chimney draught")—yet, in the face of this, they found in the forced draught trials more air supplied per lb. of coal than in the natural draught trials, and no air admitted to the gases except at the furnace front. Take trials 3 and 4, Table 3, where they had the highest evaporative efficiency per lb. of coal: the air supply was 20·3 lbs., equal to the highest supply under natural draught; and, therefore, how was it possible to have obtained a higher efficiency? In fact, he was surprised at the results obtained. Referring to trials 12 and 13, they had there the largest quantity of water evaporated in lbs. per hour, but the lowest evaporative efficiency per lb. of coal. The whole of the air holes at the furnace fronts were open, and the air was supplied at these holes under a water gauge pressure of 2·5. Then take trials 17 and 18, here they had the least air supply and the lowest ashpit pressure, and yet the evaporative efficiency was nearly equal to trials 3 and 4. In fact, when they considered the area of the holes open at the furnace front and the water gauge pressure of the air passing through those holes, and that the air practicaly converged to a common focus, judging from the position of the holes as shown in the drawing, there was no doubt the coals had been consumed at the front of the fire, very much the same as in a smith's fire. Under such conditions the calorific efficiency must have been low, even assuming part of the coals at the furnace front were consumed to carbonic acid, which gas in passing over the rest of the distilling fuel would take up another portion of carbon with the production of carbonic oxide and great loss of heat. Although Mr. Spence alluded to the funnel damper, yet, he regretted

there was no special column in Table 3 showing the position of the damper relative to the quantity of air supply, and thus he was afraid sufficient consideration had not been given to this important feature of forced draught. The damper should be so regulated as to reduce the velocity of the gases to a minimum, time was thus given for the union of the oxygen with the carbon, and for the absorption of heat by the boiler. With reference to the boiler, he was not surprised at the forced draught results; in fact he should scarcely have expected the results given. Had the coals not been good nut coals, free from dust and dirt, the high consumption per square foot of grate per hour could not have been obtained with the ashpit air pressure given. If any advantage was to be derived from forced draught, we must, not only by a judicious supply of air, materially reduce the quantity supplied, but take care it was supplied in such manner as to produce complete combustion; and furthermore, as he had stated, by the use of the damper reduce the velocity of the escaping gases. In the case of this boiler how was this to be done? The furnaces were too small in diameter to efficiently supply the proper proportion of air at the furnace fronts, for if the air, so supplied, be not converged to a focus the probability is it will pass along the furnace crown, causing considerable reduction in temperature. With this boiler how was the air to be supplied? Practically they could not supply it at the bridge, although experimentally it might have been so supplied, and also fire bars taken out, the same as in the natural draught trials. They could not supply it efficiently under the bridge, because, if they had, as they should have, materially reduced the air supply, the bulk of the reduced volume of the gas passing from the fire, due to such reduction of air supply, would pass through the upper tiers of tubes, and thus the air supply under the bridge would in all probability do more harm than good, as there was every possibility it would pass into the bottom tube without coming in contact with the gases at all. Therefore, taking all things into consideration, the boiler appeared to him most unsuitable for forced draught experiments, and the conditions under which the trials were made, particularly relative to the air admission to the gases, could not produce efficient results; and bearing in mind the natural draught results were experimental and much in excess of what could be obtained in ordinary sea practice, he was of the opinion that the final results obtained by Mr. Spence were of no value as applied to marine boilers in general use. Mr. Spence states that "In order to make a commercial success of any arrangement for raising the temperature of the air for combustion by the waste heat of the escaping gases, the heater

would require to be very efficient and of small first cost and upkeep." He was most fully of the same opinion. There could be no question every unit of heat obtained from the waste gases and returned to the furnace was a unit of heat gained but nothing more. He felt assured the cost of fitting any apparatus for such purpose to a marine boiler would much exceed the value so gained. In conclusion he might just refer to Mr. Spence's closing suggestion that the above results "point to the desirability of having a series of reliable public trials, conducted by an engineer of recognised reputation and ability * * * Say two similar type boilers were tried, one fitted up as best suited for natural draught, and the other designed expressly for forced draught, and let them both be steamed for say twelve hours per day for ten days." He must confess he did not see the practical utility of such trials. If any trials were to be carried out with a view to real practical advantage, those trials must be carried out on board a steamer in the execution of a voyage, and he was satisfied from his own experience with forced draught, which extended over some four years, the advantages gained much exceeded any natural draught results he ever had been able to obtain, and this more particularly so in the Indian trade. He should have liked to have put before this meeting data obtained from the various forced draught steamers which they have in the Indian and Mediterranean trades, but he feared he had already exceeded the time allowed for discussion, and, therefore, at some future date, if agreeable to this Institution, he should have pleasure in doing so. He again wished to repeat, relative to the proposed trials in boilers, that he held no trials would be of practical value unless made on board a steamer at sea in the execution of a voyage.

Mr. Wm. H. Scott said, he thought he should be the last man to say a word on this subject when he came in, "but who shall decide when doctors disagree?" He had had experiments on board ship. His firm had proved conclusively the advantage of the forced draught with small or duff coal as compared with the ordinary draught and the best coal. If Mr. Whyte and Mr. Fothergill desired that experiments should be made, he would be very happy to give them a free passage by one of their converted boats (the "Ferrando," that had been fitted with forced draught) for the purpose. They would put into the boat for the full voyage out and home the best steam coals instead of the duff, and he should undertake to say that the consumption of the Ryhope screened best coal would be very much less than the consumption with the ordinary draught, to the extent of 15 to 20 per cent. Since this system of forced draught had been fitted the consumption of duff had been less than with best

coals before fitting. He should be very pleased if one or both of those gentlemen would go for a trip.

The CHAIRMAN intimated that as he wished to take part in the discussion Mr. F. C. Marshall had kindly consented to take the chair.

Mr. F. C. MARSHALL, on taking the chair, wished only to say a word with reference to the experiments of Mr. Spence, and that was that whatever they were good for they were equally good for one system as for the other. It was not forced draught as against general work, but whatever the boiler was worth for forced draught it was worth for natural draught as well as forced draught. The circumstances were the same in either case, so that Mr. Fothergill's arguments did not quite apply.

Mr. ALEXANDER TAYLOR thought the meeting had not fully appreciated the benefit to be derived from this paper. The Institution was greatly indebted to the chairman and his firm for having made, and in such a liberal spirit published, the results of the valuable experiments. The Institution was also much indebted to Mr. Spence for the excellent manner in which the information had been given. He was quite sure whoever read the paper must be convinced that the experiments had been honestly carried out and faithfully expressed, regardless of what the result might be. The great lesson to him was that it reiterated (as their Chairman said) the old lesson that North Country coal must have a large quantity of air on the top of the fire. He feared this old lesson had been forgotten by many. He firmly believed that forced draught was the proper thing if an extra quantity of steam was wanted from any given boiler, but he was not prepared to say they would get it economically—he rather doubted it. It appeared to him that engineers were not looking in the right direction for securing the benefits of forced draught. They were particular about the quantity of air used, and lbs. of coal per square foot of heating surface, and the funnel temperature, but could anyone tell him the temperature of the fire under natural and under forced draught? It appeared to him that, first of all, they ought to know something more about the temperature of the fire, because, if in burning 1 lb. of coal they used 24 lbs. of air, they should have a much less temperature of fire than if they used only 12 or 15 lbs. of air. In many cases, he believed, the temperature of the fire was not duly increased as the air used was reduced, therefore, they did not get the benefit of the reduction of air, but the reduction of air was rather a disadvantage, because they had a less quantity of gas passing over the heating surface. Unless the greatest possible temperature was got in the fire, forced draught would, in his opinion, be a failure. And he would also like to ask what effect had forced draught on radiant heat? He learnt from

scientific books that half the heat of coal could be taken as radiant heat; but if, say for forced draught, the grate surface was reduced 50 per cent., did this not reduce the surface from which the heat radiated? Mr. Jobling confessed that there was no saving in quantity of coal in using forced draught, and Mr. Scott said "*they endeavoured to get the very best duff.*" Now, he firmly believed that, so far as North Country small or duff coal was concerned, it did not require forced draught to burn it, and if the duff was clean, pure coal, it was equal to large coal. During the last twelve or fifteen years he had burnt by natural draught a large quantity of small coal, which might be correctly described as pit sweepings. Of course, he acknowledged that Welsh small coal required different treatment.

Mr. SCOTT—What is the proportion when you burn the best with the worst?

Mr. TAYLOR—From six of best to eight or nine of the sweepings of the pit. He would now take Mr. Spence's experiments along with the Royal Agricultural Society's boiler tests, made in Newcastle last year, and show rather curious results. (See Table 8.) He took the mean of Mr. Spence's Tables 2, 3, 1, and 4, and placed them in this order, because the mean square feet of heating surface per lb. of coal burnt per hour increased in that order, and it would be noticed that the mean of natural draught, Nos. 25 to 31, Table 1, only were taken, and the reason was that the first twenty-four experiments only enabled Mr. Spence to determine the best conditions for natural draught, and Nos. 25 to 31 were under these conditions. The Royal Agricultural Society's tests were also ranged in order of the heating surface per lb. of coal burnt per hour. It would be noticed that, generally, the efficiency varied with the heating surface per lb. of coal burnt, and the funnel temperature decreased with coal burnt, regardless of whether the air was supplied by natural, cold forced, hot forced, or induced draught. The only apparent exception was the hot forced draught, and it was not a real exception; because, if the 9 per cent. of total heat developed by the coal, and which was necessary to heat the air, was taken from the efficiency of the hot air experiments, it would be less efficient by that amount. Broadly, the greater the heating surface per lb. of coal, the greater the efficiency and reduction of temperature in the funnel under any circumstances. If the intensity of the fires increased as the quantity of air decreased, naturally that would improve the efficiency, but, it would be noticed that, although in Mr. Spence's experiments a reduction of air went with increased efficiency, the air used in the Royal Agricultural Society's tests varied most irregularly; in fact, it was evident much had yet to be learnt. Notice No.

3,124 (Table 8), which had 6 square feet of heating surface per pound of coal, used 24·43 lbs. of air, and its efficiency was the best of all, ·84, while No. 3,114 had 6·7 square feet of surface, and used only 12·43 lbs. of air, and its efficiency was ·839 only; but the Society's Journal tells us that the funnel contained a quantity of carbonic oxide, showing a lack of air which fully accounted for its deficient efficiency. The last column gave an empirical efficiency formula. They would notice that it compared favourably with the actual efficiencies if allowance was made for the hot blast in Table 4 and lack of air in No. 3,114. He would like to remark further about the hot air; of course, he knew that some contended that this hot blast might be got from the heat of the funnel; but they must remember, if the heat was taken from the funnel the forced blast must be increased, and thus the hot air must be paid for. He again thanked the Chairman and his firm, and Mr. Spence, for the valuable information they had given to this Institution.

TABLE 8.

		Mean Heating Surface per Lb. of Coal Burnt per Hour.	Funnel Temperature Degrees Fahrenheit.	Lbs. o' Air per Lb. of Coal.	Efficiency.	$\sqrt[3]{}$ of Mean Heating Surface per Lb. of Coal Burnt per Hour × 60.	$\sqrt[3]{}$ of Mean Heating Surface per Lb. of Coal Burnt per Hour × 46.
Mean of cold forced draught experiment, Table 2		1·43	949	21·75	·661	·678	
Ditto Table 3		1·56	780	20·25	·713	·696	
Mean of natural draught experiment, Nos. 25-31, Table 1		1·76	768	19·13	·725	·726	
Mean of hot forced draught experiment, Table 4		1·82	696	18·19	·765	·732	
ROYAL AGRICULTURAL SOCIETY'S TESTS, 1887.							
Induced Draught.	Catalogue Number, 3,117 ...	1·9	480	17·43	·656		·57
	,, ,, 3,101 ...	4·7	460	27·45	·814		·77
	,, ,, 3,108 ...	4·8	440	26·20	·786		·77
	,, ,, 3,125 ...	5·4	385	23·45	·725		·80
	,, ,, 3,113 ...	5·6	435	15·22	·794		·81
	,, ,, 3,124 ...	6·0	410	24·43	·84		·83
	,, ,, 3,114 ...	6·7	388	12·42	·839		·86

Professor GARNETT (by invitation) said, there was only one point he wished to mention, because he thought if information were given upon that point it would make this paper almost as complete as it could be, and that had been alluded to by Mr. Taylor. He referred to the composition of the gases in the uptake. If this were carefully examined he thought a solution would be obtained of some apparent anomalies in the tabulated results given in the paper. For instance, in burning under forced draught, in one case there had been 26 lbs. of air supplied per lb. of coal. To raise 26 lbs. of air to the temperature of the uptake would require about as much heat as would evaporate from the boiling point between 5 and 6 lbs. of water. If to this were added the water actually evaporated, the whole amount practically corresponded to the whole calorific power of the coal, as determined by calculations or by the calorimeter. Under natural draught, when only 12 lbs. of air were supplied per lb. of coal, there was not the corresponding difference in the evaporation, so that there was a loss of something like the heat required to evaporate 2 lbs. of water. He thought this would be found to be entirely accounted for by unconsumed combustible gases in the uptake, and he was anxious to see a careful analysis made, similar to that which Mr. Pattinson made at the tests of the Royal Agricultural Society. For these analyses a considerable time was spent in collecting the gases, which were drawn into a bottle previously filled with mercury, the mercury falling out drop by drop, so that a good average result was obtained in the trial. Another point alluded to by the Chairman, was the Exhibition surplus. He (Professor Garnett) was anxious to see the Exhibition surplus. It was, however, entirely problematical at present, and depended upon contingencies about which very little was known; but if there were one he was anxious to have it applied for the benefit of the coal and engineering trades of the district. He would, however, be sorry to see it "burnt up" all at once, and would wish that the surplus, if there were any, should be supplemented,—and if there was none that it should still be supplemented,—very largely by funds from elsewhere, and that they should be able to secure a permanent engineering laboratory to be under the direction of the Council of that Institution and of the Mining Institute, for the express purpose of carrying out any such experiments as those referred to in the paper, or others which would be useful to the industries of the district.

Mr. J. C. SPENCE (by invitation) observed that the very valuable paper which they had discussed that night deserved the closest attention, not only from engineers but from coal owners and coal users in general,

and more especially from those interested in the coal trade of this district; because, if the results recorded in these experiments could be carried out and verified in actual practice, while the heating power of all coals would be increased to some extent, those coals which, like the North Country coal, contained a large proportion of gas, would have their efficiency raised to a very great extent. It had long been known that North Country coal if completely burned produced as much heat as Welsh coal, but that when burnt in the fires of ordinary boilers the gaseous part of the coal escaped almost unburnt, which not only diminished its heating effect as a fuel, but produced the nuisance of smoke. Now, as he would show from figures in this paper, Mr. Spence had succeeded in getting very nearly complete combustion of North Country coal, and if this was the case it would place it at least on a level with Welsh coal as a steam generator, a result which could not fail to have a beneficial effect in this district. But this result was not yet completely achieved. The paper contained much new matter and the most complete set of experiments that he had ever seen published. It exploded several errors which had been currently accepted; but it was not, and did not pretend to be, exhaustive of the whole subject; and it left room for a whole set of experiments to fix the best proportions in boilers of the ordinary type, in order to realise the benefits which Mr. Spence had proved to be attainable. Now, he would suggest that in any further experiments it would be of great advantage to distinguish between the efficiency of the furnace as a heat producer and the efficiency of the boiler as a heat transmitter, because if this were done it would be easy, in any case, where the highest possible efficiency was not obtained to see at once where the fault lay. If the furnace efficiency was defective, we would seek our remedy by altering our arrangement of air supply and distribution. If, on the other hand, the furnace efficiency was satisfactory, we would know that the amount or distribution of heating surface was wrong, and if we could not alter them we would at least know what to avoid in future. Now, in no experiment that he had hitherto analysed could this distinction be made, but in those now before them it was a very easy matter; for Mr. Spence gave them the amount of heat absorbed by the water from the gases and the amount of heat left in those gases in the uptake after they had left the water space, and if those two amounts were added together they would get the total amount of heat generated per lb. of coal; and if they compared that with the known heating power of the coal, which was given as 14·1 evaporative units, they obtained what he had called the furnace efficiency. Now, if they would turn to abstract of

mean results given in Plate XX., they would see the quantity of water evaporated per lb. of coal was given in evaporative units. Then they had the amount of air used per lb. of coal and the temperature in the uptake. The specific heat of these gases he got from D. K. Clarke's tables as varying from ·246 to ·242 as the air supply increased from 12 to 24 lbs. per lb. of coal. The initial temperature of the air he assumed at 60 degs., and he found that the equivalent in evaporative units of the heat in the gases in uptake was in case A = 2·2 units ; adding this to the 9·16 units given out by the gases to the water, they found that the heat produced was in this case 9·16 + 2·2 = 11·36 units (out of a possible 14·1) giving an efficiency = 80 per cent.

In the same way in case B the furnace efficiency = 84 per cent.

C „ „ 94 „

D „ „ 99 „

Now he thought this was a very remarkable result, and although they were warned by the author not to take the temperatures and air measurements as absolutely correct, yet from the care exercised in checking his instruments and getting average results, he believed they were justified in concluding that in case D the combustion was within a very small percentage of being perfect. If this was so, it was a very remarkable result, and one that demanded most serious consideration, both from engineers and also from coalowners. There was just one other point he would like to mention, if not trespassing on their time. On page 167, conclusion 4, Mr. Spence gave as one of the conclusions from his experiments, "That with a sufficient and properly distributed supply of air direct to the gases, the same rate of evaporation can be obtained from a boiler as with the air passing up through the fires only. That the coal consumption will be reduced some 10 per cent., while the smoke will be diminished fully 50 per cent. both in intensity and duration." Now, while he had not the smallest doubt that this conclusion was well founded in the boiler he had tested, he would enter a word of warning about applying this theory indiscriminately to all boilers without due allowance. If they would turn again to Plate XX., and to the table of mean results there, they would see that in case A the air per lb. of coal was at the rate of 12·25 lbs., while the air in case D was at the rate of 20·4 lbs. per lb. of coal ; also that the temperatures of gas in A was 726 degs., and in D 767 degs., so that the volume of gases passing through the chimney would in D be nearly twice that of case A. Now, he feared that in ordinary working boilers the conditions were not such that they could double the velocity of flow in the funnel, and the probable results

of adopting the methods of improving the air supply given in this paper would be that, although they might be burning their coal much more economically than formerly, they would burn much less of it, and would be short of steam, and if their boiler was formerly working up to its full power they would not get steam enough for their engines. And then they would hear again that sentence they had all heard so often, and probably used, "Right in theory but wrong in practice." Now, he ventured to say that if the great result obtained in these experiments could be obtained on the scale in which they had been tried, they could be obtained generally and regularly in ordinary practice, but that it would be necessary perhaps to modify the design of their boilers to get more chimney area, and in other ways to follow the theory to all its consequences, and that if they did not attend to these details they ran the risk of these valuable results being wasted.

The meeting agreed to hear Mr. Spence's reply to the discussion at the next meeting, to be held on February 22nd, and proceeded to the reading of the next paper.

ON THE RESULTS OF SOME EXPERIMENTS ON AN IMPROVED BOILER JOINT.

By JAMES PATTERSON.

By the kind permission of Messrs. Wigham Richardson & Co. the writer is enabled to lay before you this evening the results of some experiments recently made by the Board of Trade and Lloyd's on an improved double strapped butt joint. The main features of this joint were described in Mr. Rowe's paper on "Marine Boiler Construction and Preservation," read before this Institution in March, 1885, but may for convenience be re-stated here.

Two straps of unequal width, and with straight unscalloped edges, are used, the wide strap taking one row of rivets more each side than the narrow one. The rivets in the outer rows are thus in single shear, while the others are in double shear. Further, in the particular modification before us the pitch of the rivets in the outer row is one and a half times the pitch of the others, while all the rivets are of the same diameter. From the time when this joint was first brought under their notice, Messrs. Wigham Richardson & Co. have been of opinion that it possessed some advantages for high pressures over any of the other joints in use, notably allowing of a high percentage of strength with a close pitch of rivets for caulking. Acting on this opinion they, in 1885 and 1886, built twelve large marine boilers for 150 lbs. pressure with this joint; and from the time the boilers first had steam in them till now the joints have given every satisfaction. Then the Board of Trade and Lloyd's perceiving, no doubt, that the joint was likely to come into more extensive use, and being anxious to step surely, if slowly, in a matter of such vital importance as the strength of a boiler shell, demanded certain tests to be made before official approval could be given for its general use. After some correspondence had passed between Messrs. Wigham Richardson & Co. and the departments before mentioned, the following tests were arranged, and were carried out at Lloyd's testing house at Netherton,

near Dudley, under the direction of the Board of Trade and Lloyd's, with the result that the joint has now obtained the official approval of both bodies.

Four joints were made to the same drawing, of which Fig. 1, Plate XXVI., is a copy. The plate is $\frac{5}{4}$ inch thick, the butt straps $\frac{9}{16}$ inch and $\frac{1}{2}$ inch respectively, while the rivet holes are drilled and are $\frac{27}{32}$ inch diameter.

The plates and rivets are all of Siemens-Martin steel. The plates from W. Beardmore & Co., Parkhead Works, Glasgow, and the rivets from F. Leddicoat, Gateshead, from steel by D. Colville & Sons, Motherwell, N.B. In order to determine the quality of the material from which the joints were made, two plates were ordered as shown in Fig. 2, Plate XXVI., each 11 feet 6 inches by 4 feet 6 inches by $\frac{3}{4}$ inch, and a number of smaller test pieces were cut from them and tested.

Fig. 2, Plate XXVI., shows how the different pieces were located in the original plates. Each piece from one of the plates is marked with a reference number, and the corresponding pieces of the other plate are marked with the same number but with the letter A affixed. Those numbered 1, 2, 3, and 4, are the pieces from which the joints were made, the butt straps being from other plates ordered at the same time but not tested. No. 5 is the same width as the joint, and has holes drilled in it of the same diameter and pitch as the outer row of the joint. Nos. 6 to 12 were made into test pieces, of the nominal size of 2 inches by $\frac{3}{4}$ inch. The rivets were also tested for tensile strength.

Tables Nos. 1, 2, 3, and 4, give the results of the different tests. From Table No. 1 it will be seen that the mean tensile strength of the plates, when tested in the usual method with small test pieces, is 27·67 tons per square inch, with an elongation of 28 per cent. in 8 to 10 inches. Table No. 2 shows that the test pieces 5 and 5A give a somewhat higher ultimate stress with a much reduced elongation—the latter certainly and the former probably being due to the different shape of the test piece.

The mean ultimate stress at which the joint fractured (Table No. 3) is 226·875 tons, which shows the strength of the joint to be 87·92 per cent. of the strength of the solid plate. This is taking the nominal sizes of the plate, which is evidently the comparison wanted, and the tensile strength of the material from Table No. 1. Thus—

$$\text{Strength of solid plate} = 12{\cdot}434 \times \tfrac{5}{4} \times 27{\cdot}67 = 258{\cdot}036$$

$$\text{Strength of joint} = 226{\cdot}875$$

$$\frac{100 \times 226{\cdot}875}{258{\cdot}536} = 87{\cdot}92.$$

TABLE I.

TESTS OF STRIPS.

No.	Description.	Prepared. Size.	Prepared. Net Area.	Ultimate Stress. Total.	Ultimate Stress. Per Square Inch of Original Area.	Fractured. Size.	Fractured. Net Area.	Reduction of Area.		Length.	Elongation.		Appearance of Fracture.
		Inch.	Square Inch.	Tons.	Tons.	Inch.	Square Inch.	Square Inch.	Per Cent.	Inch.	Inch.	Per Cent.	
7	Steel Strip ...	2·00 × ·74	1·4800	40·7589	27·5398	1·5 × ·49	·7350	·7350	50·33	8	2·30	28·75	Silky.
8	,, ...	1·98 × ·73	1·4454	39·7678	27·5133	1·60 × ·55	·8800	·5654	39·11	8	2·32	29 0	,,
10	,, ..	2·00 × ·75	1·5000	42·0178	28·0118	1·55 × ·55	·8525	·6475	43·16	8	2·45	30·62	,,
11	,, ...	2·00 × ·75	1·5000	41·5892	27·7261	1·54 × ·51	·7854	·7146	47·64	8	1·20	15·00	Broke outside parallel part.
12	,, ...	1·99 × ·76	1·5124	42·6607	28·2072	1·57 × ·57	·8949	·6175	40·82	8	2·24	28·00	Silky.
$6A_1$	,, ...	2·00 × ·74	1·48	41·27	27·88	1·60 × ·56	·8960	·5840	39·45	10	2·10	21·0	,,
$6A_2$	,, ...	2·00 × ·74	1·48	40·50	29·39	1 62 × ·58	·7396	·5404	36·51	10	3·07	30·7	,,
$6A_3$	,, ..	2·00 × ·74	1·48	42·91	28·99	1·50 × ·50	·7500	·7300	49·31	10	2·5	25·0	,,
$7A_1$	,, ...	2·00 × ·75	1·50	41·39	27·59	1·60 × ·57	·9120	·5880	39 2	10	2·56	25·0	,,
$7A_2$	,, ...	2·00 × ·75	1·50	41·76	27·84	1·44 × ·50	·7200	·7800	52·0	10	3·23	32·3	,,
$7A_3$	,, ...	2·00 × ·75	1·50	41·51	27·67	1·57 × ·57	·8949	·6051	40·34	10	3·10	31·0	,,
$8A_1$	,, ...	2·00 × ·76	1·52	42 21	27·77	1·46 × ·50	·7300	·7900	51·97	10	3·21	32·1	,,
$8A_2$	,, ...	2·00 × ·76	1·52	41·94	27·59	1·54 × ·55	·8470	·6730	44·27	10	2·83	28·3	,,
$8A_3$	,, ...	2·00 × ·76	1·52	41·91	27·57	1·58 × ·58	·9164	·6036	39 71	10	2·83	28·3	,,
$9A_1$	,, ...	2·00 × ·76	1·52	41·74	27·46	1·44 × ·50	·7200	·8000	52·63	10	3·02	30·2	,,
$9A_2$	,, ...	2·00 × ·76	1·52	42·46	27·93	1·44 × ·51	·7344	·7856	51·68	10	2·87	28·7	,,
$9A_3$	,, ...	2·00 × ·76	1·52	41·90	27·56	1·48 × ·53	·7844	·7356	48·39	10	2·84	28·4	,,
$10A_1$	,, ...	2·00 × ·77	1·54	41·87	27·18	1·50 × ·52	·7800	·7600	49·35	10	2·84	28·4	,,
$10A_2$	,, ...	2·00 × ·77	1·54	41·78	27·13	1·44 × ·50	·7200	·8200	53·24	10	3·11	31·10	,,
$10A_3$	,, ...	2·00 × ·77	1·54	41·42	26·86	1·44 × ·51	·7344	·8056	52·31	10	2·88	28·8	,,
$11A_1$	,, ...	2·00 × ·76	1·52	41·66	27·41	1·58 × ·56	·8848	·6352	41·78	10	2·65	26·5	,,
$11A_2$	,, ...	2·00 × ·76	1·52	41·66	27·41	1·48 × ·50	·7400	·7800	51·31	10	3·08	30·8	,,
$11A_3$	,, ...	2·00 × ·76	1·52	41·27	27·15	1·57 × ·57	·8949	·6251	41·12	10	2·67	26·7	,,
12A	,, ...	2·00 × ·75	1·500	40·0267	26·6844	1·57 × ·57	·8949	·6051	40·34	8	2·40	30·0	,,
Mean ...	,, ...	...	...	41·582	27·67	...	...	...	45·665	...	...	28·1	

TABLE II.

PERFORATED PIECES.

No.	Description.	Prepared.		Ultimate Stress.		Fractured.		Reduction of Area.		Length.	Elongation.		Appearance of Fracture.
		Size.	Area.	Total.	Per Square Inch of Original Area.	Size.	Area.						
		Inch.	Square Inch.	Tons.	Tons.	Inch.	Square Inch.	Square Inch.	Per Cent.	Inches.	Inches.	Per Cent.	
5	Perforated piece	10·7625 × ·75	8·07187	237·14	29·37	10·24 × ·658	6·7379	1·3339	16·52	10	1·20	12	
5A	,,	,,	,,	226·12	28·01	10·07 × ·617	6·2131	1·8586	23·02	10	1·22	12·2	
6	,,	...	...	225·4	...	...	...	...	...	...	...	...	
6A	,,	...	...	225·35	...	...	...	...	...	...	...	...	
Mean...	...	...	...	228·50	28·69	...	...	...	19·77	...	...	12·1	

TABLE III.

RIVETED JOINTS

1A, 2A	Riveted joint ..	10·7825 × ·75	8·0868	233·75	28·90	10·09 × ·63	6·3567	1·7301	21·39	...	...	...	
3, 4	,,	10·7925 × ·74	7·9864	226·90	28·410	10·26 × ·61	6·2586	1·7278	21·63	...	...	...	
1, 2	...	...	...	221·8	...	...	...	...	...	...	...	...	
3A, 4A	...	...	...	225·05	...	...	...	...	...	...	...	...	
Mean...	...	...	...	226·875									

In each case the specimen broke by fracture of the plate through the outer row of rivet holes.

Referring to the drawing, and calculating by the Board of Trade rules, we find the strength of the joint to be—

	Per Cent.
1st Plate through outer row of rivets	86·42
2nd „ „ inner „ „ + shear of outer ...	89·48
3rd „ shear of all rivets	87·40

Thus the actual strength of the specimens was in excess of the calculated strength.

The following extract from the report received from Lloyd's throws some further light on the behaviour of the joint while under test :—

"The stress was then increased by increments of 10 tons up to 225 tons, the strain at which the joint broke. The slip was carefully measured at each increment of stress, and up to a strain of 135 tons the material returned to its original position; but at that strain permanent set took place, and the joint was permanently destroyed. At 225 tons the specimen broke through the solid plate across the end row of rivet holes. The sectional area of the solid plate through these holes is 8·06 square inches; the tenacity of the plate is 27·6 tons, so that 27·6 × 8·06 = 222·4 tons as the strain at which, theoretically speaking, it ought to have broken, and, as a matter of fact, it did break at 225 tons."

From this it appears that the stress at the elastic limit of the joint is 60 per cent. of the ultimate stress, and as mild steel is not often found to have an elastic limit so high as this, it may be concluded that the elastic limit of the joint is at least as high as that of the material of which it is made.

The conclusions which the writer draws from the above tests, and his opinion on the merits of this description of joint, are intrinsically of little value; but the statement of a few of them may lead to valuable criticisms from those more able to decide on such a question. He would say, then, that the results of the tests are most satisfactory, first, on account of the uniformity of result, giving confidence that, under similar conditions, similar results would be obtained; and second, because the result so closely accords with what would be expected from the accepted method of calculation; and so, if theory be practice with a soul in it, it gives a little body to the soul of the theory of the strength of riveted joints, which hitherto could only be looked upon as a disembodied spirit as far as joints with a high percentage of strength are concerned, and must still be so regarded for other systems of riveting. This opinion may of course only arise through the writer's ignorance, for undoubtedly there may have been satisfactory tests of high percentage joints with which he is not

acquainted, and he confesses he has not made any exhaustive search fo them. If any such experiments have come under the notice of othe members of the Institution, he hopes they will be brought forward Much diversity of opinion may arise as to the detail of this joint: th writer's own opinion inclines to the use of only two rows of rivets i double shear on each side of the butt instead of three, as in Fig. 1, Plat XXVI., of course in this case increasing the diameter of the rivets in thos rows to make up the required area. This reduces the width of the strap and is less costly in drilling and riveting. He also thinks there is n great gain to be obtained—unless in exceptional circumstances—in going beyond a strength of 84 per cent. of the solid plate.

TABLE IV.

RIVETS.							
No. of Rivet.	Area of Rivet.	Length before Test.	Length after Test.	Percentage of Elongation.	Breaking Strain.	Stress per Square Inch.	Diameter at point of Fracture.
		Inches.	Inches.		Tons.	Tons.	
1.	·1075	1	1·312	31·25	3·000	27·9	·24
2.	·1017	1	1·312	31·25	3·000	29·4	·24
3.	·1017	1	1·375	37·50	3·125	30·6	·24
4.	·1075	1	1·375	37·50	3·000	27·9	·23

and failed to see any necessary connection between the width of an opening and the line of its direction. The importance of assisting diffusion by splitting the air into fine jets or laminæ is stated on page 156 of the paper. He (Mr. Spence) was happy to be able to bear out Mr. Jobling's evidence as to the durability of the thin bars used. If they were allowed to project into the fire they soon got burnt or broken with the slice, but provided they were properly bedded down to begin with, and so arranged that they could not rise up, their durability under forced draught was very surprising. They outlived thick bars considerably.

The next speaker was Mr. Marshall, and he now took the opportunity of thanking him for the privilege given him of carrying out these experiments. Whether or not these tables would afford any fresh light to the members who studied them he (Mr. Spence) was not prepared to say, but the compiling of them certainly did to him. Mr. Marshall put the whole matter in a nutshell when he said that if forced draught was as economical as natural draught it would be advantageous to adopt it, as it had many practical advantages. He quite agreed with him in this, and, in that with further experiments, an increased efficiency would have been effected. Referring to the temperature curves, Mr. Marshall pointed out the serious drop observable on opening a fire door. This would be almost entirely overcome by the adoption of forced draught on the closed ashpit system, and would increase the durability of the boiler.

Mr. Fothergill suggested that still more fire bars should have been removed in the natural draught trials. This would, however, have complicated matters, by unduly increasing the percentage of ash dropping through. He also referred to the difficulty there would be in actual work in introducing as much air to the gases as was suggested in the paper, and, therefore, considered that the high results given for the natural draught trials were not a fair basis of comparison. As far as results to be expected from boats in actual running was concerned, he (Mr. Spence) quite agreed with him, but the whole object of these experiments was, as far as possible, to eliminate all indefinite quantities, and to endeavour to ascertain what increase of efficiency belonged inherently to the principles of forced draught. The mechanical advantage or economy to be effected by having complete command of the air supply, and being able to introduce it how and where they chose, he believed to be considerable, but this was simply an advantage due to a mechanically created air supply, and did not necessarily entail an increased rate of combustion. He could not, therefore, at all agree with Mr. Fothergill that a better

gauge to the advantages of forced draught was to be gained from the results of the actual logs from boats; for in these it was absolutely impossible to separate the different elements of economy, and it was only by doing so, and looking at the matter as far as they could analytically and not in the mass, that any definite guidance could be obtained for the future. This could be obtained by careful experiment alone. The inference drawn by Mr. Fothergill that he (Mr. Spence) contended the results of these tables showed there was no practical value in forced draught was quite unwarranted; for he believed that increased rates of combustion had some advantages, and that a mechanically created air supply had many practical advantages; but the two should be considered separately, being entirely distinct elements in what is known as forced draught. Mr. Fothergill referred to the air supplies being excessive in the forced draught trials. Well, he was guided greatly by the smoke, and supplied just sufficient air above the bars to reduce the smoke to about what it had been under best natural draught conditions. This he could not accomplish with a less rate of total air supply than about 20 lbs. He hoped Mr. Fothergill would see his way to carry into effect his closing remarks, and favour them at a future date with details of the results he had obtained in the boats he had fitted with forced draught. Few had had experience which entitled them to speak with more authority.

The next speaker was Mr. Taylor, who referred to what he (Mr. Spence) ventured to think was, perhaps, the most important point in the whole subject, namely, their want of any definite information regarding the temperatures obtaining in actual boiler furnaces. From one of the communications received, it would be seen that at least one member of this Institution had been attacking the subject. Until some definite information was forthcoming on this point, they must continue to be guided greatly by mere speculation. Calculated temperatures under given conditions were one thing, but what, under some of these conditions, might be the actual temperature of a boiler furnace surrounded, as it is, by such a mass of conducting matter was quite another question. It was one of the many points which could only be determined by direct experiment. Mr. Taylor submitted a very interesting table containing the mean results from the best natural draught trials, compared with the mean results from the whole set of conditions in the different forced draught tables, and by comparing these mean efficiencies with a table of efficiencies calculated on the basis that the efficiency would vary as the cube root of the heating surface ratio, showed that the results under

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887-88.

PROCEEDINGS.

SEVENTH GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, FEBRUARY 22ND, 1888.

WILLIAM THEODORE DOXFORD, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Newcastle-upon-Tyne, on February 8th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. W. Hepple and R. L. Weighton to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Cooper, William, Baltic Chambers, Quayside, Newcastle-on-Tyne.
Dixon, Raylton, Cleveland Shipyard, Middlesbrough.
Eshelby, William, 4, Lax Terrace, Stockton-on-Tees.
Mills, John, 18, Belvedere Street, Heaton, Newcastle-on-Tyne.
Pacey, John W., 45, Falmouth Road, Heaton.
Stirling, Andrew, jun., 2, Greenvale Terrace, Dumbarton.
Turner, Henry John, 11, Tindal Street, Westgate Road, Newcastle-on-Tyne.

ASSOCIATE.

Pinkney, T. W., John Street, Sunderland.

GRADUATE.

Reed, Joseph, 51, Fisher Street, Low Walker-on-Tyne.

The adjourned discussion on the paper on "The Combustion of Coal, and some Evaporative Experiments with Natural and Forced Draught" was then resumed.

This was followed by the discussion on Mr. James Patterson's paper on "The Results of some Experiments on an Improved Boiler Joint;" after which Mr. J. T. Milton read a paper on "Slide Valve Gears."

ADJOURNED DISCUSSION ON THE COMBUSTION OF COAL AND SOME EVAPORATIVE EXPERIMENTS WITH NATURAL AND FORCED DRAUGHT.

The PRESIDENT, before calling upon Mr. Spence to reply to the discussion, intimated that if there was any gentleman present who still wished to make any remarks on the paper he might do so.

Mr. M. W. SWINBURNE said, before the Chairman closed the discussion, he would like to say one word regarding that part of Mr. Spence's paper on page 166, where he referred to the admission of the air and its effect upon the smoke. Being very much troubled with the smoke as a nuisance, they were induced some time ago to try the effect of admitting jets of air into the flue. Having connected a pipe to their smithy blast pipe, they brought it to the front of the boiler, carrying it underneath the fire grate and up behind and along the bridge, keeping the top of the pipe level with the top of the bridge. The side of the pipe next the flue was perforated with two rows of $\frac{3}{8}$ inch holes, 2 inch centres. The result was very satisfactory indeed. When fresh coals were thrown on, there was black smoke for a few seconds *only*, and when the fire was stoked they had the same result. Their blast was equal to $\frac{3}{8}$ inch water pressure. He had, therefore, much pleasure in bearing out from his own experience that part of Mr. Spence's paper.

Mr. W. G. SPENCE, in reply, said, with reference to Mr. Boyd's valuable communication and table of results of the series of trials carried out at the Wallsend Slipway, he was sure they were all very greatly indebted to Mr. Boyd for laying such valuable data before the Institution. The communication and tables spoke for themselves. These trials were conducted under ordinary working conditions for nearly a whole year, and thus met some objections raised against the series he had the honour of carrying out for Messrs. Hawthorn, Leslie & Co. The results were strikingly similar to those contained in the tables in the paper, and added greatly to their value. He thought it said much for such firms as Messrs. Hawthorn and Messrs. The Wallsend Slipway Co. that before advising shipowners they would undertake these costly experiments and submit their results to the open criticism of this Institution.

The first speaker was Mr. Whyte, who, as probably most of them knew, had had considerable experience with at least one boat and one form of application of forced draught. His first point was with regard to the boiler operated upon. Mr. Whyte said, "he considered Mr. Spence had selected a very favourable boiler for getting best results from forced draught trials—the combustion chamber was large, and the heating surface almost wholly horizontal." Now, with regard to the selection, he could only say that the sole power of selection he had was the one commonly known known as "Hobson's choice," the work's boilers at St. Peter's being all of the same design. As to its being favourable for best results, he could not agree with him. The combustion chamber capacity was not abnormally large, and the furnaces were unquestionably much too small. Had there been one good 3 feet 3 inches diameter furnace in place of the two shown, he could then have understood his (Mr. Whyte's) contention. Mr. Whyte then went on to say further that "the boiler was on land—not rolling about at sea. There was throughout the same steady fireman, constant supervision, fires kept even, and grates and tubes cleaned previous to each trial; compare all this with the ordinary 'Ocean tramp,' and he thought they would see that by the end of a voyage there would be but little of even the 16 per cent. left." Now, he (Mr. Spence) entirely failed to see how all this in any way affected the point at issue, namely, the *relative* efficiencies of natural and forced draught, for even supposing all these dreadful things did happen to the forced draught boiler, would not the natural draught one have to undergo the same treatment? and excepting for some advantages which a command of the air supply would give to the forced draught arrangement, he should expect the results, though they would unquestionably be quantitively less, to still stand in a somewhat similar ratio to each other. Mr. Whyte referred to the question of trouble from fan engines frequently breaking down. Now, he was happy to be in a position to say from actual practice that fan engines did not always or necessarily break down, and provided they were placed where they got fairplay, and could be attended to, and fans fitted large enough to allow of a direct acting engine of moderate speed, say not exceeding 250 revolutions per minute, being coupled direct on to them, that they ran for many weeks without any attention except oiling. Mr. Whyte advocated the adoption of continuous working or movable fire bars. This might be good as long as they moved, but he was afraid an average fireman with an average slice would soon render their motions more erratic than efficient. Mr. Whyte submitted further the results of

two voyages of a vessel fitted with forced draught, from which he went on to prove how delusive were not only experiments on land but also actual results from sea. But in spite of this he prefaced the whole of his remarks by saying that, "in summing up the whole paper it established the conclusion at which he had arrived (after considerable experience) that the present type of marine multitubular boiler was not in any way adapted for the economical consumption of coal under forced draught." Now, how could two things, both in themselves delusive, establish any definite conclusion?

The next speaker was Mr. Jobling, who, in connection with Messrs. Scott Bros., had had an extended experience in burning duff coal on what was known as the "Ferrando" system. As far as he (Mr. Spence) could understand him, he entirely combated the idea of admitting much air above the fires, and instanced a case where under forced draught he (Mr. Spence) found it impossible to keep up steam with the chimney damper wide open, but by partially closing it he was enabled to increase the pressure. Now, that was an undoubted fact, but he by no means thought it was in any way attributable to the question of properly distributed air supply above the fire, but simply to the fact that the forced draught was fitted to a pair of old natural draught boilers having a very large funnel, which, with the damper full open and the air pressure in the ashpits, gave the gases an excessive velocity through the boiler; by closing the damper till the flame was just balanced in the fire doors, the velocity was reduced and the inrush of air in a body on opening a door prevented. Mr. Jobling also drew attention to the fact that he himself "had observed that on opening a fire door on to the first sneck the flame could be seen to drop below the furnace crown." Now, he (Mr. Spence) failed to see what satisfactory conclusion Mr. Jobling could draw from that, for admitting air by a fire door simply admitted it in a body, and did more harm than good. It would likewise cause a current to pass along the surface of the fire, which would thus lay the flame as seen from the fire door; and finally he might be pardoned for reminding Mr. Jobling that the length of a flame was a measure of imperfection in combustion. Admitting no air direct to the gases was contrary to nature, and the loss through want of it had been frequently proved in practice. Mr. Jobling, in referring to the fire bars used in Table 3, said that Mr. Spence had given one reason for their being placed crosswise, but "there was another reason he had not told them of, namely, the splitting of the air into as many laminæ or streaks as possible." Mr. Spence thought that was a question of air opening between the bars,

and failed to see any necessary connection between the width of an opening and the line of its direction. The importance of assisting diffusion by splitting the air into fine jets or laminæ is stated on page 156 of the paper. He (Mr. Spence) was happy to be able to bear out Mr. Jobling's evidence as to the durability of the thin bars used. If they were allowed to project into the fire they soon got burnt or broken with the slice, but provided they were properly bedded down to begin with, and so arranged that they could not rise up, their durability under forced draught was very surprising. They outlived thick bars considerably.

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natural and forced draught were practically alike in efficiency, but he (Mr. Spence) confessed he did not see why Mr. Taylor was entitled to compare the tables in so wholesale a manner. The real ground of comparison lay between Tables 1 and 3, and he submitted that in Table 3 the only trials that Mr. Taylor was entitled to deal with were those carried out under almost similar ratios of heating surface to coal, namely, trials 3, 4, 5, 6, 7, 17, and 18—seven in all, and, he thought, sufficient to form a fair mean. The others were under special conditions of increased or reduced ratios of heating surface, excepting trials 1 and 2, which had no air admitted direct to the gases, and for that reason must be eliminated. Now, taking these seven trials, they had a mean of 1·6 square feet heating surface per lb. of coal, and an obtained efficiency of 0·74. The efficiency as calculated by Mr. Taylor's very simple and ingenious method is 0·71, leaving the difference between 0·74 and 0·71 in favour of forced draught; and, in support of this, he would direct attention to the Wallsend Slipway Co.'s trials, which almost entirely bore out the results of these experiments. There was, however, from the difference shown in favour of forced draught a certain amount to deduct for steam used in driving the fan.

Mr. James C. Spence drew attention to the importance of separating the efficiency of the furnace as a heat producer, from the efficiency of the boiler as a heat transmitter, and, in illustration, gave the percentage of the total available heat which must have been produced in the furnace to evaporate the amounts of water and raise the temperatures of the different supplies of air. This, under each of the four groups of conditions given in Table 1, came to 80, 84, 94, and 99 per cent. Looking at the matter in this light, it would seem that under the last condition he (the writer) must have got a remarkably good result. The missing 1 per cent. they should debit to radiation, errors of observation, etc. Mr. James Spence's method of analysis, where it could be applied, was no doubt both an interesting and a valuable one. He also drew attention to the difficulty that would probably be experienced in some cases through the chimney not being sufficient to allow of the amount of air to the gases suggested in the paper being introduced without reducing the rate of evaporation. The amount of area for air direct to the gases suggested in the paper was deduced from these experiments alone, and, therefore, care must be taken in applying it indiscriminately to all arrangements of boilers, or kinds of coal. Mr. Spence, at the same time, suggested the remedy, namely, to put sufficient chimney.

In conclusion, he had to thank them for the way the paper had been received, and for the able and courteous manner in which it had been discussed.

The PRESIDENT said, there were few subjects of more interest to the members of this Institution than the one which had been so ably treated in the paper by Mr. Spence. He had shown them that under certain circumstances economy could be gained by the judicious use of forced draught; and further that there was more to be gained in ordinary draught by the judicious admixture of air than, perhaps, most of them had thought of. There was another point which he had brought forward which was of very great importance, and had been, he believed, approved of by many of the speakers, and that was the desirability of continuing such experiments under the auspices of this Institution. If it was the feeling of the members of this Institution that such should be done, the Council, he thought, would find out some means of raising the necessary funds. They had no funds at present which could be used for the purpose, but it was possible that such might be raised if the members of the Institution thought that such experiments should be carried on. Not only would they be of great importance to this district as a coal district, but the whole country would probably benefit by such experiments, as there was a very great deal yet to be learned upon this subject. He (the President) did not think he need say anything more, but the great importance of the subject, and the able way in which it had been treated by Mr. Spence, made it specially agreeable to him to have to propose a vote of thanks for his paper. He was sure it would meet with their cordial approval.

Mr. SPENCE said, there was just one matter he would like to explain. The President, in his closing remarks, appeared to be under some slight misapprehension as to the closing part of his paper. What he (Mr. Spence) suggested was that, if possible, this Institution should endeavour to secure a part of any surplus that might be over from the late Exhibition. The idea of this Institution as a body undertaking these experiments was suggested by Messrs. Patterson and Sandison, in their paper two years ago, but was not taken up by the Institution. His proposal was another way by which they might get funds for a purpose of great commercial importance to the district.

The vote of thanks was heartily accorded.

COMMUNICATIONS.

The Secretary has received the following communications upon Mr. W. G. SPENCE'S paper :—

Communication from Messrs. SMITH AND SERVICE.

54, Gordon Street,
Glasgow, 6th February, 1888.

Mr. JOHN DUCKITT,
Exchange Buildings, Newcastle.

DEAR SIR,

We are much obliged for the copy of Mr. Spence's paper on Forced Draught you kindly sent us. While we do not feel competent to express any opinion we think our experience of the "Ferrando" system may be of interest. We have used this system for eighteen months in two of our steamers trading to Eastern waters with some success, and in very many ways our experience agrees with Mr. Spence's paper. We, with "Ferrando" and suitable small or duff coal, get as good results as we formerly obtained with large coal, and our saving is consequently the difference in price. With large coal we are not able to trace any appreciable saving, but are inclined to think there is. (See Table No. 9.)

Flaming at the top of the funnel has given us some trouble, and the heat, especially in the S.S. "Mount Olivet's" uptake has at times been so great that the rooms on the bridge deck alongside of the funnel have been almost uninhabitable. With this steamer also we have occasionally been told of the difficulty in keeping up steam when the fires are being cleaned, but in the S.S. "Mount Tabor's" case there has been no such experience of either great heat in the uptake or falling off in cleaning fires.

As regards forced draught injuriously affecting the boilers, we do not find this. One engineer was advised of this, but on examination no injury or trace of it was discernable. On the other hand, the remarks of Mr. Spence as to the fires cracking on top, and jets of flame striking the furnace crown, have been observed and may ultimately have an effect. The experience we now have leads us to believe that air injected or allowed to enter the furnace above the coals would be a benefit, but at present we have no experience of this.

Yours very truly,

SMITH AND SERVICE.

COMPARISON OF ENGINE PERFORMANCES, TABLE No. 9.

Name.	Date.	Steaming Time.	Distance Run.	Average Speed. Knots per Hour.	Revolutions of Screw per Minute.	Draft.			Displacement. Scale and Mean.	Dead-weight. Mean and Actual.	Consumption per Day.	Quality.	Consumption per Day at a Speed of 10 Knots.	Consumption at a Speed of 10 Knots.			Slip per Cent.
						Leaving.	Arrival.	Mean.						Consumption per 1,000 Knots.	Per 1,000 Knots per 1,000 Tons Dead-weight.	Per 1,000 Knots per 1,000 Tons Displacement.	
														Tons.	Tons.	Tons.	
"Mount Tabor" ...	* Jan., 1886	12	2652	9·14	56·5	23·2	22·	22·7	4710	3061	16	Excellent Plymouth, Merthyr.	20·95	87·29	28·52	18·53	9·2
	† March, 1887	12	...	9·61	59·	...	...	...	4920	3200	18	Whole Coal.	20·28	84·50	26·41	17·18	3·
	‡ May, ,,	12	2673	9·28	57·18	23·	21·11	22·5½	4737	2954	17	Cardiff Duff.	21·28	88·67	30·	18·72	...
"Mount Olivet" ...	|| Feb., 1886	12	2779	9·65	56·6	22·3½	21·3	21·9	4907	3180	21·75	Cheap Cardiff, Aberdare, etc.	24·20	100·83	31·70	20·55	5
	§ Aug., ,,	13	2833	9·08	52·	22·6	21·7	22·0½	4984	3200	18·5	Cardiff Duff.	24·71	102·96	32·175	20·66	3
	¶ May, 1887	15	3278	9·10	...	...	...	...	5139	3355	18·3	Port Said Coal.	24·28	101·16	30·15	19·67	...

* Cardiff, Port Said, Ordinary Draught. † Moulmein to Perim, Forced Draught. ‡ Newport, Port Said, Forced Draught. No wind or tide; supposed by Captain to be dead steaming. || Cardiff, Port Said, Ordinary Draught. § Cardiff, Port Said, Forced Draught. ¶ Suez, Colombo, Forced Draught.

Communication from Mr. JOHN T. NICOLSON.

In making a few remarks (*few*, not because of want of suggestiveness, or of data upon which to base conclusions in Mr. Spence's paper, but from sheer lack of time on my part) it is imperative to begin by expressing indebtedness to him for the very great labour to which he has subjected himself in working out and collating these tables of results, and grappling with the uptake temperatures. The Institution may, I think, congratulate itself on having received a very valuable paper; and on having added by no means inconsiderably thereby to the data required to form a correct theoretical determination of the efficiency of a boiler.

For the remarks which are to follow, I am indebted to a distinguished student of chemistry, and friend of mine, Mr. William Somerville, whose views concerning the causes of the interesting phenomena observed in the smoke box by Mr. Spence, and recorded on pages 158 and 159 of the paper, if correct, are valuable as indicating the state of the gases as regards the supply of air at various stages of combustion.

The phenomena present a regularity in the mode and order of their appearance which points to a cause altogether different from the usual causes of colour in flames, viz., traces of metals which impart the colour proper to their spectral lines to a flame in which they are burning, it being somewhat unlikely that such traces found in the coal, would succeed each other with the regularity shown by the experiments.

Let us consider the sequence of phenomena described by Mr. Spence as occurring from 4·8 to 4·30; they are fairly representative. The red flames which begin to appear at 4·15, or seven minutes after firing, are due to the finely divided suspended particles of carbon, which when cold, we call smoke, having been heated up to a temperature sufficiently high to be luminous. This carbon being produced by the oxidising action of the air upon some of the hydrocarbons, as for example, upon ethylene according to the equation: $2\ CH_2 + O_2 = 2\ H_2O + 2C$. The dull red glow caused in the smoke box at 4·17 was, probably, merely light radiating into the smoke box from the blazing fire, caused by raking. At 4·18 the uptake becomes black again, because the gases given off are so much increased in quantity, after exposure of more coal to the fire by raking, that the heat available is no longer sufficient to render them luminous. At 4·21 we have "red flames with violet tips, violet rapidly increasing." The violet termination is, in all probability, due to the combustion of the hydrocarbons of the coal gas mixed with a mere trace of the unoxidised carbon at a red heat. The great bulk of the carbon

particles has been oxidised in the tubes into CO_2, which is incombustible and non-luminous; and the remainder, still incandescent, imparts to the dark blue flame of the hydrocarbons (chiefly methane), a tinge which might be called violet. We have, in fact, the case of the ordinary Bunsen flame. Stop the holes and the flame becomes luminous, because there is not a sufficient quantity of oxygen mixed with the coal gas thoroughly to oxidise the carbon particles; they therefore remain as suspended carbon and become heated to luminosity. Open the holes a little, and the flame will get non-luminous at the tip because, there, the oxidation of the suspended carbon particles has had time to be completed. (4·21.) The length of the violet flame increases because the quantity of suspended carbon in the flame has diminished from various causes: chiefly, the diminished supply of ethylene, which, as before mentioned, supplies free carbon by its oxidation, but also the larger proportion of air present; the total supply of coal gases having diminished, and more air being now admitted, owing to the thinner layer of fuel on the grate. (4·24.) The fuel having been by this time almost entirely distilled, coal gas is no longer given off to such an extent; and there remains on the grate a mass of glowing charcoal. Air enters below, forming CO_2, which is reduced to CO in the upper layers of glowing fuel, and burns with its characteristic blue flame; its extension into the smoke box being due to its search after oxygen.

In conclusion, I should only like to express my regret that Mr. Spence did not find it possible to record the temperatures of the furnace and the quantity of air admitted above the grate; these data would have added very greatly to the value of the results.

JOHN T. NICOLSON.

Edinburgh, February 6th, 1888.

Communication from Mr. JAMES HOWDEN.

Liverpool, 7th February, 1888.

Mr. JOHN DUCKITT,
Secretary, North-East Coast Institution of Engineers and Shipbuilders, Newcastle-on-Tyne.

DEAR SIR,

I would have had pleasure in being present to-morrow evening at the discussion of the paper, "On the Combustion of Coal," etc., by Mr. W. G. Spence, who has kindly sent me a copy of the paper with an invitation to be present at the discussion; but being engaged here I find I will be unable to go to Newcastle by to-morrow night, and must

therefore content myself with sending some remarks which I understand will have the favour of being read at the meeting of the Institution.*

The paper gives a very clear statement of the principles of combustion, and of the experiments carried out in the boiler operated on under the conditions specified, the apparent results being evidently very carefully noted and tabulated.

The experiments, otherwise, are to me interesting in that they travel over ground which formed the round of experiments I made with forced draught in a boiler exactly 26 years ago this month. I then proved clearly that neither with thick fires, nor with thin, nor with any variation of air pressure, could proper combustion be effected by admission of air to the ashpit only. This is a fact for which it has been difficult for me to obtain recognition, for though I have particularly referred to it in my various papers on the subject, it is given in Mr. Spence's paper apparently as a newly ascertained fact.

Mr. Spence's experiments also touch, so far, on the ground which I began six years ago to test practically, and which trials I continued over a period of two years. These experiments were made for the purpose of determining, as far as possible, the proper proportions of air above and below the firegrates for various rates of combustion, conditions of furnace, lengths of firegrate, and differential air pressures above and below the firegrate, also the effect of various modes of air admission. These various conditions under which combustion may be effected, I have described more or less in the paper read before the Institution of Naval Architects in 1884. Another point which I found necessary to examine was the effect of treating, in the same manner, different kinds of coal. Besides the various Scotch coals, I experimented with at least five other distinctly different kinds of coal. One of these, West Hartley coal, was from your neighbourhood, and from the description given by Mr. Spence, of the coal used in his experiments it was evidently much of the same character. A few particulars of my experience of this coal may be interesting. It was of fine quality in round pieces of usable size; there was no small coal. It was burnt on a grate 4 feet 3 inches in length, bars $\frac{3}{4}$ inch on top with air spaces $\frac{3}{8}$ inch wide. Coming after a trial of Scotch coal, I expected a higher evaporation from it, but at first got less The air admission above bars which burnt the Scotch coal perfectly without smoke was quite inadequate for the West Hartley, and for a considerable part of the trial I had great difficulty in preventing the emission of

* This communication was not received till the day following the meeting.

thick black smoke. Before finishing I found, however, that this coal required not only a difference in the supply of air, but also in its treatment in the furnace, in regard to the quantities supplied each time and also in relation to the condition of the fires when fresh coal was laid on.

After experience showed how to use this coal judiciously, a much better result in evaporation and in preventing the emission of smoke was obtained with a less air admission than was at first found necessary to prevent very heavy smoke. Up to the time of this trial I had not previously tested any coal which evolved in combustion so large a proportion of coal gas. Such trials as these, and many others, made under various conditions, showed me how unwise and misleading it would be to lay down any general rules from the results of a few experiments.

I am unable to refer to all the points suggested by Mr. Spence's paper, but I will touch on one or two more. Taking the quantity of air required for complete combustion in any given case it may be more or less according to the manner of admission. In the mode of admission above the grate, adopted by Mr. Spence, a larger quantity is required than is necessary under a more suitable arrangement. The pressure available to throw the air over the grate is rather less than that in the ashpit. I have clearly proved by trials, and it is easily comprehensible when explained, that with a higher air pressure above than below the grate, smaller jets and a lesser quantity of air can be made more effective than a larger quantity admitted with less velocity. The control of the furnace is also very defective with the arrangement used by Mr. Spence. In my complete system, the admissions top and bottom are quite separate and can be used effectively under any circumstances. When very slow speed is required the whole air of combustion may be conveniently admitted entirely from above.

Looking at the records of the trials on the several tables in Mr. Spence's paper I have no hesitation in saying that the natural draught trials have not had quite fairplay. With the gaseous coal used, a chimney of considerably greater height than 35½ feet was absolutely necessary to burn the coal properly with natural draught.

The abnormally short grate also, of the forced draught trials, will show results which will not coincide with trials made with grates of the ordinary length, say from 4½ to 5 feet long.

The reduction in size of grate in a sea-going steamer is limited by the rate of combustion and the accumulation of incombustible material in a given time. A grate in a steamer must, therefore, not be less than is required to burn an average quality of coal without having to clean fires

at less than the usual intervals. Not much practical guidance is, therefore, obtained from experiments with a grate about 21 inches in length. The very limited air spaces through the fire bars are also much out of usual practice. I find fire bars $\frac{3}{4}$ inch thick with air spaces $\frac{3}{8}$ inch in width, or about one-third the area of the total grate surface, very suitable for all kinds of coal, and usable under the ordinary stoking routine. In some locomotives which I have examined I find a similar proportion of air space to total grate, which appears to suit even the very high air pressure at which locomotives work.

These points, which from my experience I think worth mentioning, may throw some light on the considerable differences in the results obtained from the forced draught trials with the grates as in Plates XIII. and XV., and which, I consider, show the desirability of not attempting to generalise from trials of this character.

As this letter is growing lengthy, I will conclude with referring to the hot air forced draught trials and the deduction therefrom as to the comparatively small value of hot air in combustion which Mr. Spence rather too confidently makes.

There is the largest possible array of facts, well known to every one conversant with the subject, as to the great value of hot air in promoting economy in combustion. The history of the introduction of the hot blast in smelting is too well known to need any description here.

When first introduced, the air was only heated to about 400 degs. Fah., but the increase of temperature in the furnace and the reduction of weight of fuel required to produce a ton of iron was remarkable, and apparently out of all proportion to the few hundred degrees of increase of temperature in the air of combustion. Since then the temperature of the air of combustion has been continually increasing in smelting furnaces, with a corresponding increase of economy in fuel and efficiency of furnace.

My own experience in boiler furnaces has been entirely in keeping with all previous experience as to the great benefit derived from the use of heated air.

The experiments of Mr. Spence, on the contrary, if they prove anything, prove that hot air is prejudicial to economical combustion, and the higher the temperature used the more hurtful the effect. They are almost what one would look for from the use of a mixture of carbonic acid with the air of combustion, the percentage of carbonic acid increasing as the temperature increased. This mixture would reduce the temperature of the furnace and neutralise the economical effect of the hot air by taking up the carbon from the furnace and passing off as carbonic oxide. The

apparent correctness of the idea of some such process as this having taken place is borne out by the results given in Table 4, where the lowest temperature of the air of combustion gives the highest evaporative economy, and the highest temperature the lowest evaporative economy, while the temperature of the escaping gases on the average right through, is less than in the cold forced draught trials in Table 3.

As the air in the hot forced draught trials is heated some 200 degs. above the temperature of the atmosphere used in the cold draught trials, and also leaves the boiler at a lower temperature than in the cold draught trials, it would be interesting to discover what has become of this 200 degs. odds of temperature which have disappeared from the total products of combustion passing through the boiler—not a small percentage of the total units of heat utilised by the boiler.

In my system, the air of combustion is heated by the hot escaping gases. This mode of heating the air not only utilises a considerable amount of heat which is otherwise wasted, but also interposes a restriction which serves indirectly highly useful purposes in regard to control, and economy in fuel. To give a comparative example, I take the case of the "Ohio," where, on certain trials, the proportion of heating surface to coal consumed—a fair mode of comparison—was even less than in this experimental boiler, or, 1·7 square feet per lb. of coal, the evaporation was found by measurement to be over 13 lbs. of water per lb. of Welsh coal. These facts prove my system to be very different in its results from the hot forced draught trials of Mr. Spence.

I remain,

Yours faithfully,

JAMES HOWDEN.

Communication received from Mr. A. BLECHYNDEN.

Barrow-in-Furness,

9th February, 1888.

At the present day, and in connection with the discussion upon Mr. Spence's paper, I should not be inclined to make much of the trials* to which Mr. Spence refers in the letter which I have received from him. They were made with the object of ascertaining three things: viz., what amount of coal could be burnt per square foot of grate with given air pressures in the stokehold; what amount of water the boiler would

* Referring to some experiments Mr. Blechynden carried out for Messrs. R. & W. Hawthorn & Co. on a semi-locomotive type marine boiler in 1883.

evaporate per lb. of coal under these conditions; and, principally, how the particular form of boiler itself would behave with fires working under a severe stokehold pressure.

As a matter of fact the trials were very useful. They showed that while the coal was being burnt under great stokehold pressures and in large quantities per square foot of grate, a reasonable return in water evaporated was had for the expenditure of fuel. During these trials practically the whole of the air supplied to the fuel passed through the grates, and under this condition it was found that, so far from forced draught permitting a smaller quantity of air to be used per lb. of fuel, 22 to 24 lbs. were required with all stokehold pressures from about one-half to about three inches of water. The fires were kept of such a thickness as to enable the fuel to be burnt just without visible smoke, and the coal was best hand-picked Nixon's Navigation.

I have made many experiments relative to coal economy, and in the winter of 1885 I organised and had partially carried out a series of experiments on fuel combustion and evaporative performance, which was unfortunately, however, interrupted by illness. These were carried out both upon a small and a large scale, and were designed with a view to the settlement of several points upon which I was in doubt or held certain theories, which, up to the moment, as they had been put to no careful experimental test so far as I knew, I could only regard as speculations wanting proof, though they were, apparently, founded on sound reasoning.

The most interesting of the series were carried out with a pair of boilers of the ordinary vertical donkey form of different proportions, fitted with plain cylindrical fire boxes without cross tubes, and as a collateral experiment the gases were passed through a small cylindrical horizontal tubular boiler, the object of the latter experiment being to test whether, with equal quantities of gas at the same temperature passing through the tubes, a short tube of large diameter was equal to, greater than, or less than a longer tube of small diameter but with equal surface in evaporative efficiency.

The ashpit was enclosed in brick and the air was supplied by a blower, between which and the ashpit there was a large receiver, so as to keep a pressure in the ashpit less subject to sudden changes owing to variations of the velocity of the blower.

The whole of the air for combustion passed through the fuel on the grate. The fuel used in the experiments, the means of whose results are given, was coke, containing, by analysis, about 95 per cent. of carbon; but experiments were also made with Welsh coal and wood charcoal.

During the trials the fires were fed with machine-like regularity in small and uniform quantities at a time, these quantities being weighed at fixed periods during the course of each trial, and the supply of air was regulated so as to maintain a pressure in the furnace equal to the atmospheric pressure and just sufficient in quantity to prevent carbonic oxide being formed, which was ascertained by the appearance of the fire and by periodically testing the products of combustion at a flame.

The greatest care was taken to ensure accuracy.

The boilers were filled with measured quantities of water as nearly at boiling point as possible, the temperature of the water supplied being taken, and allowance being made for the difference which the temperature made in the weight of the measured volume when the boilers were filled. When filled the temperature of the water in the boilers was carefully measured, and the first charge of fuel, of known weight, was put on the grate at red heat, having been heated in a closed iron pan. The blast was then started. From a known series of trials it was ascertained how much fuel was required to raise the temperature of the water in the boilers from degree to degree up to boiling point, and this was allowed for. The water was fed to the boiler at atmospheric temperature, which was carefully noted periodically, and the supplies of water were weighed. At the termination of the trial the air supply pipe, the fire door, and the flue were immediately closed and the fire quenched, and further evaporation prevented by allowing a known quantity of the feed to flow into the boiler. The weight of water in the boiler was then ascertained, and the amount evaporated during the time of the experiment. The weight of unconsumed fuel in the grate was also ascertained.

An allowance was made for the heat radiated from the surface of the boilers as an equivalent amount of water evaporated. This radiation of heat was ascertained by allowing the water in the boiler to cool from boiling point, the openings to the interior of the furnace being carefully closed, and the water kept circulating within the boiler in the meantime. The temperatures within the boilers, and of the air outside, were carefully noted at equal intervals, and from this the amount of heat lost by radiation per degree *difference* ascertained.

Shortly, the results were as follows :—

The fire box heating surface per lb. of fuel burnt per hour ...	1·395 sq. ft.
Heating surface in tubular boiler, per lb. of fuel burnt per hour	·818 ,,
Evaporation from and at 212 degs. per lb. of fuel	10·386 lbs.
Tubular boiler	1·332 ,,
Total	11·718 ,,

So far as could be ascertained, the short and the long tubes of equal surface gave about the same results.

One of the points which I wished to determine was the following :—

It has long been held as part of the gospel of combustion that the temperature of the gas leaving the incandescent fuel can be ascertained as follows :—Let

H Represent the units of heat in 1 lb. of the combustible ;
A Lbs. of air supplied per lb. of combustible ;
S Specific heat of the products of combustion ; and
T Temperature of the furnace, then

$$T = \frac{H}{(A + 1) S}.$$

That the gases are at this temperature as they leave the fire, and remain at this temperature until they come in contact with the surface of the boiler.

I was quite prepared to admit that the temperature of the fire might be thus approximately estimated, and that the gases at the instant of leaving it were consequently at this temperature ; but whether, in the furnace of a steam boiler, they remained at this temperature when they left the solid mass of fuel, or not, was a point about which I was doubtful. It will be remembered that Rankine founds his formula for approximately estimating the efficiency of a furnace on the above assumption, and that the gas, thus heated, passes at uniform velocity over the surfaces of the boiler, gradually cooling by contact with them until they leave the flues. It appeared to me that this must be wrong ; and that by far the larger amount of heat absorbed by the plates surrounding the furnace was due to radiation from the incandescent mass of fuel in it, and that after leaving the fire the gases themselves could not be at the temperature of the fire. To ascertain this definitely, the temperatures of the fire and the gases in the furnace were repeatedly and carefully measured during the course of the experiments referred to. These measurements were made with a Siemens' pyrometer. The mean of these temperatures, taken during the set of trials of which the mean results of evaporation have been given, are as follows :—

Temperature of the fire	2,520° F.
Temperature measured, the pyrometer just touching the incandescent fuel	2,184° F.
Temperature measured, the block being just clear of the solid fire	1,705° F.
Temperature measured with the block $\frac{1}{2}$" to $\frac{3}{4}$" clear	1,254° F.
Temperature of the gases escaping at the end of the tubular boiler	524° F.

Perhaps these facts may lead to a modification of the calculation of the speed of the gases passing through the boiler, made on page 155 of the

paper. I am led to think that it is essentially immaterial as to evaporative economy whether air is admitted entirely below or partially above and partially below the bars, if the fires are kept of such a thickness as will just permit the necessary quantity for complete combustion to pass through them. But, as this perfection of stoking is impossible under ordinary conditions with the human factor at the shovel, it is the most efficient mode of working to keep the fires sufficiently thick to prevent the above quantity of air to pass through, the furnace thus becoming a gas producer. To get complete combustion it is then necessary to supply the balance of air above. So long as there is no excess over that necessary to ensure this complete combustion, I am of opinion that the particular ratio of the two supplies is not important. It may, however, be found that some particular ratio is more favourable to easy stoking than another. Another reading of the results of Mr. Spence's experiments might perhaps be that the maximum efficiency is attained with a supply of about 20 lbs. of air per lb. of fuel. I offer this, however, without having gone so carefully into the matter as Mr. Spence has done in the light of his experiments. If we select from his results irrespective of forced or natural draught (which are terms, as it appears to me, that had better be dropped in the scientific treatment of the subject, and total motive pressure substituted in their place) and arrange the results relatively to the quantity of air supplied per lb. of fuel, with approximately equal heating surfaces per lb., it will be seen that there is a gradual rise in efficiency up to just over 20 lbs. These are shown in the following table :—

EVAPORATIVE TRIALS WITH THE BOILER FOR DANISH GUNBOAT "GRONSUND."

Lbs. Air per lb. of Fuel.	Heating Surface per lb. Fuel, square feet.	Water Evaporated.
12·25	1·73	9·166
13·14	1·68	9·260
13·80	1·70	9·360
14·04	1·64	9·280
16·59	1·62	9·62
16·83	1·635	9·46
17·27	1·65	9·68
17·35	1·74	10·33
18·00	1·71	10·27
18·17	1·64	10·01
18·46	1·74	10·25
20·30	1·66	10·675
20·35	1·64	10·390
20·39	1·79	10·190
20·71	1·73	9·430
21·86	1·6	10·350

I have been led to the above opinion from other data, and this given appears to strengthen it. It is, however, quite possible that my reading of the data may require some modification. It will be observed that a higher result than any recorded in the paper was obtained in the experiment, to which I have previously alluded, with the entire quantity of air passing through the fuel alone.

A. BLECHYNDEN.

(Mr. W. G. SPENCE'S replies to communications.)

Mr. W. G. Spence is much indebted to Messrs. Smith and Service for their valuable communication and table of results. They are sufficiently explicit to require no further comment.

To Mr. Howden, the writer believes, engineering is as much indebted as to anyone for the introduction of economically applied forced draught; he cannot, however, help regretting that during his 26 years' experience he has not seen his way to publish results which were sufficiently detailed to allow of readers forming a more independent judgment. He is also afraid Mr. Howden has hardly read the paper with sufficient care, for referring to the importance of supplying air direct to the top of the fire, his communication states—"This is a fact for which it has been difficult for me to obtain recognition, for though I have particularly referred to it in my various papers on the subject it is given in Mr. Spence's paper apparently as a newly ascertained fact."

If Mr. Howden will refer to page 172 he will find that after pointing out the necessity of a plentiful supply of air direct to the gases it continues as follows:—"It seems strange . . . . . that so little effort is generally made to improve the design of the furnace . . . . . although the benefits to be derived in this direction were very fully laid before engineers as early as the year 1841 by the late Mr. C. Wye Williams, to whose works the writer is indebted for much guidance in this matter. It is quite within the mark to say that at the present moment, by far the greater number of marine boiler furnaces have no provision whatever for burning the coal gas they generate, as the little air that is admitted direct above the grates is quite inadequate for the volume of gas generated from North Country coal, and is seldom even sufficient for the quantity that would be necessary for a coke fire." Also on page 172 he will find the following:—"It also appears to the writer (and the annexed experiments seem to bear this out) that of the saving which *has already been actually obtained in practice* by the application of forced draught, a

considerable portion must be credited to the more *enlightened methods of air introduction* which the advocates of this system have usually introduced when fitting their forced draught apparatus, etc."

From the above it will be seen that this paper does not give the subject "as a newly ascertained fact," but attributes its introduction to a man who did obtain recognition, and who both published his views thereon and largely applied them in practice quite twenty years previous to the experiments of Mr. Howden.

In reference to Mr. Howden's remarks on the advantages of raising the temperature of the air on its way to the grates by passing it through the waste products of combustion, the writer can only say that under forced draught the economy to be obtained by so doing is unquestioned, and is to a great extent a calculable amount; he does not, however, believe that the increase of efficiency that would be obtained in practice would compensate for the necessary outlay and complication, and thinks that some good arrangement of feed-heater would be a more practically beneficial method of economising the loss due to the high temperature of the waste gases. The results obtained by heating the air in these experiments are simply given as they were obtained, and are fully borne out by the Wallsend Slipway Co.'s trials. Mr. Howden after giving several reasons for the smallness in the increase of economy shown in the heated air trials clinches his arguments by adding—"The apparent correctness of the idea of some such process as this having taken place is borne out by the results given in Table 4, where the lowest temperature of the air of combustion gives the highest evaporative economy, and the highest temperature the lowest evaporative economy, while the temperature of the escaping gases, on the average right through, is less than in the cold forced draught trials in Table 3." Taking the first contention, namely, that "the lowest temperature of air of combustion gives the highest evaporative economy:"—The temperature of the air of combustion is not the only thing to be considered, the ratio of heating surface to coal is, to use Mr. Howden's own words near the close of his letter, "a fair mode of comparison." Now the means of the three sets of trials in Table 4, stand thus:—

Temperature of air	261	256	242
Ratio of heating surface	1·77	1·78	1·96
Efficiency	0·761	0·756	0·784

The first two columns, it will be seen, are practically alike; the third has undoubtedly a higher efficiency, with a lower temperature of entering air, but this is the mean of trials 6 and 7, the series with reduced rates of evaporation and the ratio of heating surface to coal considerably

increased. If Mr. Howden's remarks refer to differences of temperature between individual trials of any one set, as say 1-2-3, it will, I think, be at once seen, on reference to them, that any slight inconsistency shown is nothing more than is always observable between the units that go to to make up any mean from practical experiment.

With regard to his second point, namely, that the temperatures of the escaping gases are, in Table 4, less than they are on the average right through Table 3, and that "it would be interesting to discover what has become of this 200 degs. odds of temperature," the reason is not far to seek. At the bottom of Table 3 is to be found the following note:—"Owing to an accident to the pyrometer, the temperatures in trials No. 7-17-18 were calculated by dropping 4 ozs. of copper into 20 ozs. of water and noting the rise in temperature of water;" and below Table 4 likewise we have—"Owing to an accident to the pyrometer, the temperatures in all the above trials were calculated, etc." It being imperative to complete the trials within the dates given in the tables, the only thing that could be done on the pyrometer becoming disabled was to extemporise another, which was done in the way indicated in the notes. The constant loss by such a rough-and-ready method must be something appreciable, and as nothing is added to allow for it, the approximate temperatures obtained would naturally be below these obtained with an instrument like Siemens' pyrometer. Now the temperatures in all the trials except those marked thus (*) are distinctly stated in the paper to have been obtained by a Siemens' pyrometer, and thus in Table 3 the only trials that can legitimately be compared with those in Table 4 are 7-17-18. If this be done it will be seen that under similar rates of coal burnt per hour the temperatures of the uptake in the heated air trials are, throughout, higher than 7-17-18, and just about agree with the small increase in efficiency. Had Mr. Howden noted the asterisks, he would have found it less difficult than "interesting to discover what had become of the 200 degs. odds of temperature." In concluding, the writer cannot help again alluding to the service Mr. Howden has rendered by his unwearied efforts to introduce forced draught as a commercial success in the merchant marine. If by his system he can continue in practice to evaporate 13 lbs. of water per lb. of Welsh coal with 1·7 square feet heating surface per lb. coal, it must soon become widely adopted.

Mr. Spence has also to thank Mr. Blechynden for his very valuable communication. The quantities of air admitted up through the grates in the first set of trials to which he alludes seem to indicate that the fires did not much exceed the thickness of ordinary natural draught fires. The

results appear to bear out those conducted at St. Peter's by the writer on some torpedo boat locomotive boilers in this, that with thick fires, increasing the air pressure under the grates does not materially increase the ratio of air to coal, but simply the rate of combustion. Mr. Blechynden's endeavours in his second set of experiments to grapple with the furnace temperatures are well worthy of further continuation, and if the series of trials suggested in the paper were carried out some important information might be obtained on this at present somewhat speculative subject. In reference to Mr. Blechynden's closing remarks, the writer would point out that Mr. Blechynden used coke as fuel, whereas in the trials given in the paper a highly gaseous coal was employed; and it is well known that it is easier to effectually burn the former than the latter and that it likewise requires less air supplied direct to the gases.

The writer is also much indebted to Mr. John T. Nicolson for the valuable suggestions he has forwarded in reference to the phenomena observed in the uptake. This subject might be very fully gone into in the experiments suggested. By analysis of the gases and flames in the uptake under varying rates of air supply, much valuable information might be obtained.

Communication from Professor Garnett.

April 20th, 1888.

Five samples of gas were collected from the uptake under different conditions with regard to the admission of air. Unfortunately Mr. Spence was not able to be present, and it is probable that the conditions were not quite the same as in the case of any of his experiments. The large six-inch tube at the bottom of the boiler appeared to be open, and through this a considerable volume of flame passed into the smoke box, when no flame was observable at the end of any of the other tubes. A very large amount of heat appeared to be wasted through this flame, but no tests were made of the evaporative efficiency of the boiler.

After the air supply had been adjusted, five minutes were allowed to elapse before the collection of the gases commenced, and ten minutes were occupied in the collection of each sample. It would have been better if a much longer time could have been devoted to the collection of the gases, as ten minutes was scarcely long enough to give an average sample or account of the intermittent firing of the boiler.

The results of Dr. Bedson's analyses of the five samples of gas are as follows, the percentage composition being given in volumes:—

	A.	B.	C_1.	C_2.	D.
Carbonic anhydride ...	10·1	11·3	10·4	11·6	9·95
Olefiner	—	—	—	—	0·3
Oxygen	7·6	6·7	6·5	7·2	9·2
Carbonic oxide	·4	1·05	1·05	—	0·4
Nitrogen	81·5	80·8	82·4	81·2	80·3
	99·6	99·85	100·35	100	100·15

Accepting Mr. Pattinson's analysis of the coal employed, and supposing no smoke to have been produced, the amount of carbon present in the gases may be taken as representing the coal consumed. From the amount of carbon, and the analysis of the coal, the amount of consumed hydrogen has been calculated. The oxygen required for the combustion of the hydrogen has been calculated, and from it the oxygen present in the coal has been deducted. The remainder, together with the free oxygen in the products of combustion and the oxygen in the carbonic anhydride and carbonic oxide produced, has been taken as representing the oxygen of the air consumed, and from this the amount of *dry* air supplied per pound of coal consumed has been calculated. The results are as follows:*—

In A there were 16·94 lbs. of air per pound of coal.
„ B „ 14·60 „ „ „
„ C_1 „ 15·27 „ „ „
„ C_2 „ 16·19 „ „ „
„ D „ 18·46 „ „ „

The excess of air supplied over that required for the complete combustion of the coal was:—

In the case of	A	38·7 per cent.
„	B	31·8 „
„	C_1	31·8 „
„	C_2	35·7 „
„	D	43·8 „

As a rule the combustion was more perfect the greater the amount of air supplied. The following amounts of carbon escaped as carbonic oxide for each pound of coal consumed:—

In the case of	A	·03067 lb.
„	B	·06845 lb.
„	C	·0738 lb.
„	D	·0311 lb.

Taking the thermal value of the unconsumed carbonic oxide in the four cases in which its quantity was determined, we have a loss of the following amounts of heat, viz.:—

In A 309·15 Fah. units, or 2·27 per cent. of the total obtainable.
„ B 689·98 „ „ 5·06 „ „ „
„ C_1 743·90 „ „ 5·46 „ „ „
„ D 313·49 „ „ 2·30 „ „ „

No experiments were made with forced draught, but in the worst case examined it would not be economical to increase the supply of air by more than about 2 lbs. of air per pound of coal, even if complete combustion could be thereby secured, on account of the high temperature of the uptake.

It seems desirable that further experiments should be carried out and that the gases in the uptake should be analysed when the air supplied is reduced to 12 lbs. per pound of coal, and also when, in the case of forced draught, it is raised to double this amount.

* Mr. Spence is of opinion that the plate covering the air holes in the top of the bridge was not properly placed during these experiments, and that the very slight variation in the air supply was due to this cause.

DISCUSSION ON THE RESULTS OF SOME EXPERIMENTS ON AN IMPROVED BOILER JOINT.

(FEBRUARY 22ND, 1888.)

Mr. J. T. MILTON said, he had given a great deal of attention at times to the proportioning of boiler joints, and to this joint amongst others. He thought they must thank Mr. Patterson for putting the results of the paper before them; but he was sorry he did not quite agree with him in his conclusions. He believed he was amongst the minority of those present in this respect. Some two or three years ago he (Mr. Milton) read a paper before the Institution of Naval Architects on the strength of riveting. In that paper he pointed out that the ordinary way, which Mr. Patterson, he thought, called the *accepted method* of calculation, should not be applied for determining the strength of such riveting as that shown. He thought if they looked carefully into this paper, it bore out his (Mr. Milton's) view of the subject. There were two views in regard to strength of riveting which were generally taken, but neither of them took into consideration all the conditions of the case. The *accepted method* was the first way of looking upon the subject. This plan assumes that the stress on the joint is uniformly distributed all over the joint, and that the joint is practically rigid, that there is no yielding in any part of it, or if there is, it is uniform at each part of the joint. Neither of these conditions are actually fulfilled in practice, so that looking upon it in this way is only one step to the solution of the problem. The other method is to look to the yielding on each part, and assume still that similar parts of the joint are similarly strained, and that the stresses on each detail of the joint are uniformly distributed. But that even is not a final solution of the problem. If the strains upon any cross section are considered, it is seen that the plate behind the rivet holes is in a state of compression, while half-way between the rivet holes the plate must necessarily be in a state of tension. In passing from the one point to the other the stress must gradually change from the condition of compression to that of tension; these stresses being in opposite directions, the mean stress cannot be anything like the maximum stress. He (Mr. Milton) had pointed out in the paper he read that if they looked to the stresses on the rivets, they should see that in all, except the single

or double riveted lap joints, the different rows of rivets had different stresses upon them. To show that that was so in practice, he mentioned some experiments made by Messrs. R. & W. Hawthorn when they were beginning to make steel boilers. They proposed to use a triple riveted lap joint, having three equal rows of rivets. The first joint they proposed was tested to destruction, and the rivets sheared at a stress of 22 tons per square inch. They had originally been proportioned as iron rivets would be to iron plates, and it was thus seen that steel plates required a larger rivet section. Another specimen of a joint was made with larger rivets, but with the same pitch and lap; this proved to be a great deal stronger, but again the rivets sheared at the same stress, viz., 22 tons to the square inch. They then made a third joint, reducing the distance between the rows of rivets, but retaining the same diameter and pitch of rivets. In this joint the plate gave way, the rivets withstanding a stress of 25 tons to the square inch; so that by closing up the rows of rivets they increased the apparent strength of the rivets from 22 to 25 tons per square inch. The reason for this being that in the last joint the stress was more equally distributed between the three rows of rivets. The part of the plate between the middle and inner rows of rivets had a stress equal to that upon two rows of rivets, the part immediately adjacent to it had only the stress upon it given by the resistance of one row and, therefore, was stretched less than the contiguous part of the other plate. The result of that was that the outer rows of rivets became considerably more deformed than the middle row, which, consequently, did not take its fair share of the strain. Looking at it in that way, the results obtained by ordinary method of calculation could only be used as approximations to the actual strengths; and in his (Mr. Milton's) opinion, it was unfair to compare any riveted joint with the results obtained from another unless the conditions were very nearly the same. Now, Mr. Patterson, he thought, implied in his paper, that because the strength of the joint as he found it, viz., 87 per cent., was equal to the calculated strength, and because an ordinary treble riveted lap joint would have a calculated strength of say 75 per cent., the strength of this joint would be greater than that of the treble riveted lap joint in the proportion of 87 to 75. He (Mr. Milton) did not think this true. The ordinary accepted method gave a result as generally applied to ordinary joints much within the actual strength of the joint. That this was so, he need only to refer to some experiments by Mr. Traill, published in 1881, in a little book called "Experiments on Steel." Over and over again through this book Mr. Traill adduced the actual strength

of rivet joints as well beyond the calculated strength. In this book of Mr. Traill's, for instance, at page 13, it states that with drilled holes riveted joints had 6 per cent. more strength than the calculated strength; and right through the whole of this report the results showed the actual to be considerably in excess of the calculated strength. In this joint the actual strength came out much the same as the calculated strength; and, therefore, a boiler made with this kind of joint, proportioned in accordance with ordinary rules, would not be so strong as one made with the common form of joints would be. Another point deserved some little notice: Mr. Patterson had given them the mean strength of the two plates, and it was a rather singular thing that the joints made from the weaker plate had proved to be the strongest joints in both cases. It was wrong to generalise from the result of one or two experiments; but, if they showed anything, these experiments showed that structures made from *mild* steel were likely to be stronger than those made of equal scantlings of *harder* steel. He might say that in the experiments made by Professor Kennedy, he found that in some cases the excess of strength at the point of fracture was as much as 15 per cent. over the calculated strength. In other cases he found it 6 and 7 per cent., and only in one case in all his experiments did he find it below the calculated strength. Another point that seemed to be clear from the experiments made was that the milder the steel the greater was the strength in excess of the calculated strength.

The PRESIDENT—Have you any reason for the excess?

Mr. MILTON—It was due to the material not having the same chance of being drawn out, and having its sectional area reduced at its weakest section near the holes, as in the plain strip.

Mr. F. C. MARSHALL observed that, probably, no one had had so much to do with riveted joints as Mr. Milton. Perhaps he might tell them to what cause he attributed, or Mr. Traill attributed, increased strength to the calculated strength?

The PRESIDENT—That is just the point I put to Mr. Milton.

Mr. MILTON said, the reason was that in forms of this sort, the length of the weakest section only bore a very small portion of the whole length, and as soon as they got past the weaker section, they came to one of greater width which prevented the material thinning down between the holes so much, and by maintaining a greater cross section than a long thin strip having the same original section, they obtained a greater ultimate strength, because the moment it thinned down it lost strength proportionately with its loss of area.

The PRESIDENT—Has friction anything to do with it?

Mr. MILTON—No; for a single plate perforated showed the same peculiarities. The American engineers seemed to know that matter very well. The law in America required that all boiler plates should be tested for strength, and that the strength in pounds per square inch shall be stamped upon each plate. It was their custom in testing the plates, instead of taking a long piece of 8 or 10 inches, to have a short piece, notched in at the sides. By this means they got a very high apparent tensile strength out of what might be a very poor quality of material.

Mr. J. A. ROWE (by invitation) took part in the discussion. He thought, to some extent, Mr. Milton had been misleading them, perhaps unknowingly, for so far as his statement was concerned regarding Mr. Traill's experiments with riveted joints, the result was exactly the contrary of what he had stated. Instead of a joint becoming stronger at the test, the results of the experiments in the book to which Mr. Milton referred were these—that with the ordinary 60 to 70 per cent. joint, or any *low* percentage joint, they found that the actual strength was very much greater than the calculated strength; but as soon as they began to increase their percentage, they began to decrease the difference between the actual and the theoretical, until when they came to a 75 per cent. (or 80 per cent. joint at the most) the variations swung round in favour of the theoretical; and it is probable that none of those who proposed the testing of this 86 per cent. joint dreamt that it would yield as good results as its calculated strength. He would quote Mr. Milton's own words on the subject. In the paper read by him in March, 1885, before the Institution of Naval Architects, in referring to this particular joint, he said:—"In my opinion, if a joint of this description was used in the boiler of ordinary scantlings calculated upon the percentage of area rule, it would be found that the hydraulic test would so strain the single shear rivets as to render it difficult to keep them tight, and he did not think the actual strength of the joint would be much more than that of the double-strapped portion that would be left if the extra strips were cut off." Thus, in 1885, Mr. Milton was of opinion that this joint, with a theoretical strength of 86 per cent., would possess a strength of only 76 per cent. Now he is not surprised at learning that its actual strength is considerably in excess of its theoretical strength. Surely there was something inconsistent in this. So far as the straining of the rivets in single shear was concerned, he pointed to the twelve or thirteen large marine boilers that had already been built, tested, and worked, and not a rivet had been either strained or proved leaky. Mr. Milton concluded his paper by saying:—"What is required with this new form of joint is

some reliable experiments in regard to its strength, from which to gain efficient data by which it can be compared." Well, as if in answer to Mr. Milton's request, this type of joint had been tested, and had shown excellent results; and he thought that, as scientific men, they ought to come to facts, give up prejudices (if he might say so), and accept the result of tests; otherwise of what use was it for manufacturers to make tests in order to satisfy the requirements of the Admiralty or other officials? He wanted to call attention to a point which occurred in Lloyd's report, and was a little misleading to those who had not studied the subject. In Mr. Patterson's paper he quoted Lloyd's report, and said:—"The stress was then increased by increments of 10 tons up to 225 tons, the strain at which the joint broke. The slip was carefully measured at each increment of stress, and up to a strain of 135 tons the material returned to its original position; but at that strain permanent set took place, and the joint was permanently destroyed." It was with reference to the remark that the joint was "permanently destroyed" that he wished to say one or two words. Nearly all present were aware that in testing steel plates they usually employed strips, about two inches wide, and long enough to take the extension—Lloyd's in eight inches, and Board of Trade in ten inches. Now, in testing carefully, observers had discovered that up to a stress of about 16 tons per square inch, the steel, when relieved from stress, returned to its original length; but beyond a force of about 16 tons, extension took place, and that extension was permanent. That point was generally spoken of as the elastic limit of mild steel. That was to say, if they had a complete boiler shell, made without any joints (no seam in it), if they subjected it to hydraulic test until 16 tons per square inch or above was reached, then the whole material of the boiler would be extended, the circumference would be longer, the diameter greater. Now, if this stress would do that to a solid plate, they must expect it would do it to a joint; and really that is what did take place with those joints, and nothing more. Now, in Lloyd's report, it said:—"Up to this strain of 135 tons the material returned to its original position, but at that strain *permanent set* took place, and the joint was *permanently destroyed*." The sectional area of the joint was 8·06 square inches, and the strain required to produce "slip" was 135 tons. If they divided the one by the other, they would find that the result was 16·7 tons. Well, it was surely not expected that the joint was not going to stretch after the elastic limit of the metal was reached, yet the passage quoted might suggest to some minds that slip resulted from a faulty arrangement of rivet. It simply yielded to a law of nature, just as they must all yield when the time came.

The PRESIDENT having invited other speakers, without response, said this was perhaps a small subject, but it was still very important. He thought it rather a pity not to have further discussion upon it; but if there was no one to follow, he would call upon Mr. Patterson to reply.

Mr. ROWE, interposing, wished to say how exceedingly obliged he was to Messrs. Wigham Richardson & Co. for having confidence in his judgment, and for having given him the opportunity of proving whether there was any value or not in this description of joint.

Mr. JAMES PATTERSON said, he was rather surprised that they had not had more critical remarks upon the joint described, because he was sure there were a great many points quite open to criticism. There never was a boiler joint made without some bad features as well as good ones.

Mr. Milton being the sole unfavourable critic, had expressed his opinion that the joint was not as good as he (Mr. Patterson) thought it was, because it only gave a strength equal to that calculated by the accepted method of calculation. Now, the grounds upon which he came to the opposite conclusion had, he thought, been pretty well explained by Mr. Rowe. In looking through a series of experiments of boiler joints, it was found that, for joints that gave a low percentage of strength, the actual strength was found in excess of that calculated by the accepted method; but as they rose to higher percentages of strength the actual strength approached the calculated, until they became equal at about 70 per cent., leading irresistably to the conclusion that if joints of still higher calculated strength were tested they would be found to fall below that strength. He therefore thought that the tests just described must be looked upon as giving a higher actual strength than could have been predicted for the joints from any previous experiment. Of course there was a great difference of opinion as to the way the strength of the joints should be calculated; for the joint can only resist stress by strain of its material, and therefore it is not sufficient to take merely the area of material into consideration, but the strain possible to each part of the material of the joint due to its position must also be considered. He thought the way they designed the joints now gave the material a better chance than in the test joints. Instead of having three rows of rivets in double shear, they only used two, making the diameter of the rivets larger. That brought the rivets nearer their work, and allowed the extension of the material to act more equally. So he would expect, on testing a joint riveted like this, to find it stronger in comparison with its calculated strength than the one actually tested. Mr. Rowe seemed to be over

anxious about any misunderstanding with regard to the elastic limit of the joints; but he thought that would be understood if the paper was carefully read, as the elastic limit of the joint was quite according to the elastic limit of the material.

The PRESIDENT had much pleasure in proposing a vote of thanks to Mr. Patterson for his thoroughly practical paper. He could only express his sorrow that there had not been a longer discussion upon it. As Mr. Patterson said, there was no joint made but what some faults might be found with it, and further discussion might have shown how the proposed joint could be still further improved.

The PRESIDENT then called upon Mr. J. T. Milton to read his paper on "Slide Valve Gears."

SLIDE VALVE GEARS.

By Mr. J. T. MILTON, M.I.N.A.

[Read before the Institution, February 22nd, 1888.]

The problem of how to impart a suitable motion to the distribution valves of steam engines is one which has met with several solutions, various descriptions of gear having been proposed for the purpose. In this paper it is intended to notice a few points of interest in connection with some of those which are used at the present time, it being impossible to treat exhaustively upon the merits or demerits of any one gear within the limits of a paper, and it will be principally to the *motion* produced that attention will be directed.

The requirements of a Valve Gear for marine engines include not only the necessity of giving such a distribution of steam as will enable the engine to work economically when in full-ahead gear, but also such as will ensure the engines readily starting from any position both ahead and astern; and further, it must be capable of giving a satisfactory result when the engines are "linked up" and working at less than full power; the latter consideration in war vessels being very important, as most of their cruising is done with the engines developing considerably less than their maximum power.

For illustrating the motion of the valve produced by any gear, the method used will be that known as Zeuner's. Several valve gears are illustrated by this method in Zeuner's treatise on valve gears, and particular reference to some of them will be made in the course of this paper.

In this method of representing motion, polar co-ordinates are used, the distance the valve has travelled from the centre of its motion for any particular angular position of the crank shaft being represented by the distance measured along the crank, or along a corresponding radius, when in that position. For illustration, let the case of a slide valve actuated by a single eccentric be taken.

In Fig. 1, Plate XXVII. let C be the centre of the crank shaft, and A B a line passing through the centre in the direction of motion of the slide

valve. Let A P B be the circle described by the centre of the eccentric, then the total travel of the slide valve will be equal to A B. Also if P be any given position of the centre of the eccentric, then, neglecting the obliquity of the eccentric rod, if P D be drawn perpendicular to A B the position of the valve from the end of its stroke will be represented by the distance A D, while D C will be its distance from the centre of its travel. If now along C P a length C E be set off equal to C D it will be found that the point E will always lie upon a circle having A C as a diameter, or upon the equal circle having B C as a diameter. (By joining A E it will at once be seen that A E C and P D C are equal and similar right-angled triangles, and since the angle in a semicircle is a right angle, E will always fall on the circumference of the circle.)

If, therefore, in any case A B be drawn parallel to the direction of the motion of the valve, and C A, C B be each made equal to the eccentricity of the eccentric, or half the travel of the valve, and upon C A and C B as diameters there be described the circles A E C, B F C, then for any position of the centre of the eccentric, represented by P′, if C P′ be joined, the distance C E′ will represent the corresponding distance of the valve from the centre of its travel, and the valve will be above or below its central position, according as the line C P′ cuts the upper or lower of the two circles. These circles are called Zeuner's valve circles.

These circles, drawn as in Fig. 1, represent the motion of the valve by the distance along the radius representing the *position of the centre of the eccentric*, but in general we do not so much require to know the motion of the valve corresponding to the position of the *eccentric* as we do its motion corresponding to a given position of the *crank*.

Let the eccentric be at any given angle α in advance of the crank: in Fig. 2, Plate XXVII. if A B be the line of centres, and if the angle B C P $= \alpha$, C P will be the position of the crank when the eccentric is on the top centre and the slide valve at the upper extremity of its motion. Hence, if C P be made equal to the eccentricity, and on C P and C P produced the valve circles be drawn as before, these circles will represent the positions of the valve corresponding to the positions of the crank represented by the radii. If the angular positions of the crank and eccentric are coincident the angle α is zero, and the circles become, as in Fig. 1, the upper circle representing the position of the valve during the upper half of its motion, while the lower circle represents it during the lower half. If, however, the angular position of the eccentric is opposite to that of the crank $\alpha = 180°$, and Fig. 1 still represents the valve motion, but with the difference that the *upper* valve circle represents

the distance of the valve *below* its central position, and the *lower* valve circle represents its distance above that position.

In the ordinary case where the eccentric is placed at some angle between 90° and 180° in advance of the crank, the diagram becomes the ordinary well-known valve diagram shown in Fig. 3, Plate XXVII. where B C D is the angle by which the eccentric precedes the crank, and where, accordingly, F C E, D C G are each what is ordinarily called the angle of advance. In this diagram the upper circle represents distances of the slide *below* its central position, and the lower circle corresponding distances *above* its central position.

To use this diagram the circles H K N and O P are drawn with radii equal to the outside lap and the inside lap respectively of the upper end of the valve. Then for the upper side of the piston C H will be the position of the crank at which the valve first opens to steam, K L will be *lead*, F M the maximum port opening, C N the position of the crank at the point of cut off, C P its position when the release commences, and C O its position when the exhaust port closes. Similar constructions will give like data for the lower side of the piston.

Instead of supposing the valve to be acted upon by one eccentric only, suppose its motion to be such as would be imparted by two eccentrics acting simultaneously; such a motion for instance as would result from some mechanism which if acting alone would give a motion identical with that produced by one eccentric, while the whole mechanism receives an independent motion similar to that derivable from another eccentric (Kirk's and Bryce-Douglas' valve gears shown in Figs. 21 and 22, Plate XXX., represent cases of this description); it will be seen that the resulting motion of the valve will be exactly the same as that which would be produced by a third eccentric having a particular position and eccentricity depending upon the angular positions and the eccentricities of the two first eccentrics.

For example, let the motion be such as would be derived from that of an eccentric having its centre at A superimposed upon the motion derived from an eccentric with its centre at B. (See Fig. 4, Plate XXVII.) Then if A E and B F be drawn perpendicular to the line of centres, the position of the valve, so far as it is influenced by the eccentric A, will be at a distance C E to the left of the centre of its travel; and so far as it is influenced by B, it will be a distance C F to the right of the same centre. If E G be set off equal to C F, it will be seen that G will represent the actual position of the valve. If now A D and B D be drawn parallel to C B, C A, meeting in D, it is evident that G is the

position which would be derived from an eccentric having its centre at D. This holds true for every position of the eccentrics during the whole revolution of the shaft.

(This proposition is proved mathematically by means of polar co-ordinates in Zeuner's treatise when discussing the motion of Meyer's expansion valve.)

It is thus seen that, neglecting the obliquity of the eccentric rods, if a valve is actuated by the combination of two motions, each of which, if it acted alone, would be such as could be produced by an eccentric, the resultant motion will be exactly the same as that which would be produced by a third eccentric having a position and eccentricity determined by the construction described. This is very important, and does not appear to be so fully recognised as it deserves to be, as the opinion is often expressed that the motion produced by the combination of two right-angled movements causes the valve to move more quickly when opening and closing the steam ports and to move less rapidly when at the extremities of its motion than would be the case if the valve were moved by one circular motion only.

With most valve gears in general use it will be found that, except so far as concerns small differences in the motion produced by the obliquities of the rods, or in some cases by substituting slightly curved for straight paths for some parts of the gears, the motion produced is essentially such as might be produced by a single eccentric suitably placed. To show this diagrams will first be drawn representing the motion which would be produced if the obliquities, etc., were neglected, and then other diagrams will be given representing the actual motion produced by the gears as used in practice.

Take the case of the ordinary Stephenson link motion. When the link is in full gear and the end of the valve rod is brought fair with the end of one eccentric rod, the motion of the valve is of course exactly the same as would be produced by that eccentric alone, the motion of the other eccentric not producing any effect on the valve; but when the link is put over in some intermediate position each rod produces an effect upon the valve's motion.

For example, in Fig. 5, let A B be the link and suppose the slide to be worked from a point C, intermediate to A and B, then the motion of C will be produced by the action of both eccentrics and will be similar to the motion of B, reduced in the proportion of $\frac{A\,C}{A\,B}$, superimposed upon the motion of A reduced in the proportion of $\frac{B\,C}{A\,B}$.

If O be the centre of the shaft and D be the centre of one eccentric and E that of the other, then if O D and O E be joined and O F be made equal to $O D \times \frac{B C}{A B}$, and $O G = O E \times \frac{A C}{A B}$ the part of the motion of C obtained from A will be such as would be produced by an eccentric having its centre at F; while that part of the motion which is obtained from B will be such as would be derived from an eccentric having its centre at G. Hence, if F H be drawn parallel and equal to O G, it follows that the actual motion of C will be that which might be obtained direct by an eccentric having its centre situated at H.

It is evident that H falls on D E, and that it divides D E so that $\frac{D H}{H E} = \frac{A C}{C B}$.

It is thus seen that, neglecting for the moment the obliquities of the rods, if in Fig. 6 A and A^1 are the centres of the valve circles representing the motion produced by the go-ahead eccentric, and B and B^1 the centres of the valve circles representing the go-astern motion, then, if A B, A^1 B^1 be joined, the motion of the valve produced by intermediate positions of the link, when working "linked up," will be represented by valve circles having their centres falling upon A B and A^1 B^1 and dividing them in the proportion which the working point divides the length of the link. Also, when in mid-gear the motion would be the same as that produced by an eccentric situated diametrically opposite that of the crank.

When the effect of the obliquities of the eccentric rods is taken into account, the motion of the valve when "linked up" is still identical with that which would be produced by a particular eccentric, the centre of which, however, lies near but not upon the straight line joining the centres of the two actual eccentrics. The mathematical proof of this is given in Zeuner's treatise, and from the results there deduced, Figs. 7 and 8, Plate XXVII., are drawn, the differences between these figures and Fig. 6 showing the effect produced by the obliquities of the eccentric rods. Fig. 7 represents the case of *open* and Fig. 8 that of *crossed* rods.

Next consider two forms of valve motion originally introduced by Hackworth, and the modifications of these forms known as Marshall's system.

In each of the two styles of Hackworth's gear the motion is obtained from one eccentric, working in an eccentric strap or lever, the general direction of which is at right angles to that of the slide rod. One point (or fulcrum) of this lever is constrained to move in a straight line, the inclination of which may be varied, and the motion of the valve is

taken from another point of the lever. In one form of gear the eccentric is placed opposite to the crank and the motion is taken from a point between it and the fulcrum, while in the other type the eccentric is placed in the same radial direction as the crank, and the motion of the valve is taken from a point in the lever on the side of the fulcrum remote from it.

The principle of these motions is shown in Fig. 9, Plate XXVIII. Here C is the centre of the shaft, A the centre of the eccentric, A B the centre line of the eccentric lever, a point B in which is constrained to move in a straight line which always passes through O, but the direction of which may be varied between the limits K O L and G O H; E O F, the mean position of this line, if produced, passing through C. The position of B, in the lever is such that when A is on the top or bottom centre B will fall at O. It follows therefore, that at whatever inclination K O L may be set, the position of the lever is always the same, and therefore also the position of the valve is the same, when the eccentric (or crank) is on either centre. In other words, with this kind of gear the lead is constant for all degrees of "linking up." The slide rod obtains its motion from the point D or D′ in the lever, which point will move in a curved path. The vertical component only of the motion of D will be transmitted to the slide, and this vertical motion is obtained partly from the vertical motion imparted to the end A of the lever by the eccentric, and partly from the vertical motion of the end B. The motion imparted to it by A is $\frac{D\ B}{A\ B}$ times the vertical motion of A, and that by B is $\frac{A\ D}{A\ B}$ times the vertical motion of B.

The vertical motion of B is always equal to its horizontal motion, multiplied by the tangent of the inclination of the guiding line to its mean position; and since the horizontal motion of B is that produced by the eccentric A, the vertical motion of B must also be proportional to the horizontal motion of the eccentric A. The two points A and B of the lever A B will therefore have their vertical motions such as would be produced by eccentrics at right angles to each other, the motion imparted to the slide rod by A being that due to an eccentric radially in the same direction as the actual eccentric, but with an eccentricity equal to $\frac{D\ B}{A\ B}$ times that of the eccentric, while that imparted by B is due to an eccentric at right angles to the other, with a throw equal to $\frac{A\ D}{A\ B}$ × tan inclination times that of the actual eccentric.

The latter of these is the only part which admits of variation. When the inclination of the guiding line is zero, the vertical motion of

B becomes zero also; and when the inclination becomes reversed, what was an upward motion becomes a downward one, and *vice versâ*.

In the form of gear in which the motion is taken from the extreme end of the lever the eccentric is placed in radial line with the crank, and so the motion as affected by A, being reversed by the fulcrum being towards the centre of the lever, is in the same direction as in the other gear in which the eccentric is placed diametrically opposite to the crank.

Fig. 10, Plate XXVIII., illustrates the motion produced by both gears (still neglecting the effect of the angular motion of the lever). Here

$$C\,A = \text{throw of eccentric, and}$$

$$C\,D = \frac{D\,B}{A\,B} \times C\,A; \text{ also if}$$

$$C\,B = \tan \alpha \times C\,A,$$

α being the maximum angle of inclination of the guiding line, make

$$C\,E = \frac{A\,D}{A\,B} \times C\,B,$$

then the motion of the valve will be that due to the combination of the motions of eccentrics having centres situated at E and D respectively. Hence, by drawing E F and D F parallel to C D and C E, it is seen that the motion is such as might be produced by a single eccentric with its centre at F.

For "linked up" positions, since it is only the effect of B which is variable, the motion will be such as would be produced by eccentrics with centres situated at F_1 F_2, etc., along the line F D, where F_1 D bears the same proportion to F D as the tangent of the inclination of the guiding line in its "linked up" position does to the tangent of its maximum angle of inclination. Similarly, for the astern gear, we see that if D G = D F, the astern motion is such as would be produced by an eccentric having its centre at G.

If account be taken of the obliquity assumed by the lever in its various positions, Figs. 11 and 12, Plate XXVIII., represent the actual motions produced. As may be seen, the curves representing these motions differ very little from circles, and the gears still retain the property of giving a constant lead.

In Marshall's system the constrained point instead of moving in a straight line, which involves making it move in guiding grooves or the use of a parallel motion moves in the arc of a circle. This is effected as shown in Figs. 27 and 28, Plate XXXI. In these systems there is a difference in the amount of the motions of the top and bottom portions of the travel of the valve, owing to the difference in the mean inclination

of the arcs described by the end of the pendulum link, but this difference becomes less as the proportion between the length of the pendulum link and the throw of the eccentric becomes greater.

Figs. 13 and 14, Plate XXVIII., show the actual motion obtained by these forms of valve gearing, both when in full-ahead and full-astern gear, and they also show the motion in intermediate or "linked up" positions of ahead gear.

It is only necessary to draw attention to the valve gears, described by the late Mr. Wyllie in his paper read before the Institution of Mechanical Engineers, Figs. 29 and 30, Plate XXXII., to see that they are essentially the same as those here described, the *swinging link* gear being identical with one form of Marshall's system, with the direction of motion changed by the introduction of a bell-crank lever, while the *sliding block* gear, Fig. 30, is a form of Hackworth's motion, with the direction similarly changed. The motion, described by Mr. Mudd during the discussion on the paper, is also an application of one of the forms of Hackworth's gear.

In Joy's valve gear, eccentrics are entirely dispensed with, the whole of the motion being taken from the connecting rod. Fig. 15, Plate XXVIII., shows an arrangement of this gear suitable for vertical engines (reproduced from the figure given by Mr. Joy in his paper, read before the Institution of Naval Architects in 1885). H K represents the connecting rod, H being the centre of the piston rod crosshead, and K the centre of the crank. A rod, A B C, has one end jointed at A to a point A fixed in the connecting rod, and the other end C jointed to one end of a radius link D C, the upper end D of which is fixed. The end A therefore describes an oval figure during the revolution of the shaft, the vertical diameter of which is equal to the stroke of the engine, and the greatest horizontal diameter of which is equal to $\frac{H\,A}{H\,K} \times$ stroke of the engine. The end C describes an arc of a circle about D as a centre, an intermediate point B of the rod A C describes therefore another oval curve, the greatest vertical diameter of which is approximately $\frac{B\,C}{A\,C}$ times the vertical traverse of A, while its horizontal diameter is approximately equal to the horizontal traverse of A, that is, equal to $\frac{H\,A}{H\,K} \times$ stroke. A lever B E F has one end jointed to B, the other end actuates the slide rod by means of the slide connecting rod F G, while the fulcrum E is constrained to move in a circular arc by being suspended to a pendulum link. The direction of the constraining arc is varied in a similar manner to that adopted in Marshall's system.

The motion of the slide is thus similar to that produced by Marshall's system, that is to say, it is such as might be obtained by the combination of the motion produced by an eccentric situated opposite to the crank, having an eccentricity equal to $\frac{E\,F}{E\,B} \times \frac{B\,C}{A\,C} \times$ crank, with that produced by an eccentric situated at right angles to the crank, having an eccentricity which is variable, according to the position or inclination of the arc in which the fulcrum E is compelled to swing, and which may be reversed in direction by suitably fixing the position of the arc. By means of the latter or variable part of the motion various grades of expansion are obtained, as also is the astern motion, precisely in the same way as in Marshall's system.

Fig. 16, Plate XXIX., shows the actual motion produced by Joy's gear. It is seen that in this gear the lead is constant, and also that the curves representing the motion are very approximately circular.

In the valve gears introduced by Messrs. A. C. Kirk and A. D. Bryce-Douglas the similarity of the motion produced to those produced by the gears already described is easily seen. In the former, shown in Fig. 21, Plate XXX., and in two of the gears by the latter, shown in Figs. 22 and 23, Plate XXX., the motion is transmitted to the valve from a quadrant which oscillates about a point situated on the air pump lever, or on a lever similarly worked. The motion of the valve is thus compounded of the motion of the lever and of the oscillation of the quadrant. The first part is directly proportional to the motion of the piston, and is therefore, such as would be produced by an eccentric situated opposite to or radially with the crank according to the side of the lever gudgeon to which the quadrant fulcrum is attached. The oscillation of the quadrant is produced by different means in the three gears, but in each case it is nearly proportional to, and is synchronous with, the horizontal movement of the point in the connecting rod from which the motion is first derived. Its effect on the valve is, therefore, approximately the same as might be produced by an eccentric placed at right angles to the crank, with a throw proportional to the distance to which the end of the slide connecting rod is moved from the fulcrum of the quadrant. By moving the slide connecting rod to the other end of the quadrant, the direction of this part of the motion is reversed, and a motion suitable for going astern is obtained.

In Figs. 17, 18, and 25, Plate XXIX., are shown in a similar manner as in the previous cases, the curves representing the resultant valve motion produced by these gears for astern, full-ahead, and intermediate degrees of ahead gear.

In another gear, shown in Fig. 24, Plate XXX., introduced by Mr. A. D. Bryce-Douglas, an eccentric is fixed to the shaft in such a position that its dead points are at 90 degs. from those of the crank. The end of the eccentric rod is constrained to move in a circular arc, the position of which admits of variation. From the end of the eccentric motion is transmitted by a link and a bell crank lever to the fulcrum of another lever, one end of which is attached to the slide connecting rod and the other end to the piston rod crosshead. The motion of the slide is thus compounded of a motion obtained from the piston rod with one obtained from the eccentric. By suitably altering the position of the constraining arc the amount and direction of the latter can be varied and different degrees of expansion obtained. Fig. 26, Plate XXIX., shows the actual slide motion produced by this form of gear.

Although the main features of the motions produced by all these gears are alike, yet the slight differences produced by the obliquities of the rods, etc., are in some cases important, as they affect the motion at some of the critical points, such as at the instants of opening and closing of the steam and exhaust ports; they also affect the extent of openings of these ports when the valve is at the extremities of its travel. These influences can be seen by comparing the valve motion curves with Zeuner's valve circles.

Perhaps the most important of these differences is seen in the case of Stephenson's link motion, when comparing the gears with *open* and *crossed* rods, the differences being especially noteworthy in engines in which short eccentric rods have to be used.

In all cases of the gears examined in this paper "linking up" for cutting steam off earlier is accompanied by a diminished valve travel and therefore by a contracted port opening, and because the speed of the engine is not reduced in the same proportion as the port opening, it follows that the velocity of steam through the ports when "linked up" is always greater than when working with full link, and consequently the wire drawing is greater also. If Figs. 7 and 8, Plate XXVII., be compared with Fig. 6 it will be seen that for the same relative cut-off when "linked up" with the two gears, that with *open* rods gives a greater port opening and, therefore, wiredraws the steam less than that with *crossed* rods. It is this peculiarity which causes the *open* system to have the preference. On the other hand, we see that with this gear "linking up" increases the lead and very considerably advances the position of the crank at which the port opens first to steam, causing with high degrees of expansion a looped indicator diagram, whilst with the *crossed* rods the *lead* becomes

less with the high degrees of expansion, and the position at which the port opens is not nearly so much advanced as with the other system.

In Marshall's gear it has been noticed that the substitution of the pendulum link for the straight guides of Hackworth's system causes a difference in the mean inclination of the curved paths of the constrained point and renders the top and bottom portions of the valve's travel unequal. This is usually remedied by constructing one end of the valve with an extra steam port.

In both these gears the lead is usually made constant for all positions of "linking up," but it may be, and sometimes is, slightly varied by altering the position of the eccentric from being exactly opposite to, or in line with, the crank. In Joy's, Kirk's, and two of Bryce-Douglas's gear the lead is always constant, the motion being derived from the connecting rod, and being, therefore, the same as would be derived from an eccentric exactly in line with the crank.

In considering the motion of valve gears it is important to bear in mind the effect which may be produced in the motion by the want of adjustment occasioned by wear and tear. Looked upon in this light the effect of undue wear may be far more important as regards economy than any question of the cost of repairs to the gear, as a faulty motion may involve a direct loss of useful effect and, therefore, a direct pecuniary loss during each revolution of the engine.

In Stephenson's link motion there are eight sets of wearing surfaces subject to motion during the running of the engine, viz., two eccentrics, two eccentric rod ends, the sliding of link block in the link, the rotation of link block in the eye of the slide valve, and the two ends of the drag links. The effects of wear upon this gear are well understood. That of the eccentrics and eccentric rod ends is to shorten the effective length of the eccentric rods and so to lower the slide, thus virtually increasing the lap at the lower edge and lessening that at the upper edge. This, so far as one eccentric is concerned, may be remedied either by lining up the eccentric rod to make it the same length between the centres as before, or by merely raising the valve on its spindle. The latter is usually the easier done, but unless both eccentric rods have worn to an equal extent, this method throws the gear out of adjustment not only for going astern, but also for working "linked up."

In Hackworth's gears there are only five moving parts subject to wear, viz., the eccentric, the two ends of the slide connecting rod, the sliding or guiding blocks of the fulcrum, and the joint of the lever with the sliding block. In Marshall's gear the number of parts are the same,

the two latter being replaced by the ends of the pendulum link doing the same work. These ends are more easily kept in order, and more easily adjusted than the sliding block. The effect of wear upon the slide connecting rod and pendulum link is to shorten each of them. In the case of the former it lowers the valve, and of the later it somewhat raises it, in both cases the effect is the same, for all positions, ahead or astern of the gear, so that an adjustment, whether made on the rods themselves or on the slide spindle, if correct for one position is correct for all. The effect of wear of the eccentric is slight.

In Joy's gear there are eight wearing parts in the gear proper, in addition to the top and bottom ends of the connecting rods, making ten in all, in which wear, affecting the valve motion, takes place. In order to keep the valve motion correct, the shortening of the connecting rod, due to wear, must be corrected at *both* ends, not at *one* end only, as is usual when its effect on the clearance alone is considered, and a small amount of wear in the connecting rod, which might be disregarded if it were not for the valve gear, must be at once allowed for. The wear of the pendulum link D C must also be compensated for to preserve the proper motion of the point B. The effect upon the motion, caused by the wear of other parts of this gear, will be the same as in the second form of Marshall's gear, to which this part of Joy's gear is similar.

In Bryce-Douglas's and Kirk's gears there are still more wearing parts, the want of adjustment of each of which will more or less affect the resultant motion. Speaking generally, the wear of some of these parts will affect the ahead and astern motion to the same extent and in the same direction, while the wear of other parts will affect these motions in opposite directions, so that in making adjustments of these gears, it will in general be necessary to adjust each of the several parts of the gear.

In comparing one gear with another, however, it must be borne in mind that it is not sufficient to take into account only the number of the working parts involved, but due consideration must also be given to the loads coming upon the various parts, as these, of course, considerably influence the amount of the wear. As an illustration of this, the two forms of Marshall's gear may be taken. In each of these gears the number of working parts is the same, but the loads on the parts are very different, as may be seen by referring to Figs. 19 and 20, Plate XXIX. In Fig. 19, if A B be the position of the pendulum link, B C that of the lever in its extreme position, and D E the direction of the slide rod, it is evident that for any given load on the slide rod the load on the eccentric sheave must have a direction passing through E, and the

loads on A B, D E, and on the eccentric in the direction of C E, must be in equilibrium; hence, if we draw B F parallel to C E, the lengths of F E, B F, B E, will be proportional to the loads on the slide rod, eccentric, and pendulum link. In this way it is seen that taking the load on the slide rod to be unity, that on the pendulum link will vary between 1·1 and ·65 for the go-ahead position, and from ·73 to ·83 for the go-astern positions; while that on the eccentric varies from ·55 to ·89 when going ahead, and from ·49 to ·82 when going astern.

Applying the same method to the other form of gear, in Fig. 20, we find that the loads on the pendulum links vary from 1·4 to 2·4, and on the eccentric from ·5 to 1·5 times that on the slide rod; so that in this form of gear the loads are more than twice as great as in the other, and unless the wearing surfaces are increased in the same proportion, the amount of wear must be much greater.

As was pointed out in the beginning of this paper, it is impossible to fully deal with all points in connection with these gears in the limit of one paper, and it is impossible also to describe all the methods which have been used and proposed for working slide valves. It will, however, be found that in most of the gears the motion really is derived from that of two moving parts, and that the variations of motion giving the variations of expansion are produced by combining these in different proportions.

In concluding, it should be mentioned that since commencing this paper the attention of the writer has been drawn to a pamphlet published at Paris last year by Monsieur A. Madamet, in which this subject has been treated in a somewhat similar manner.

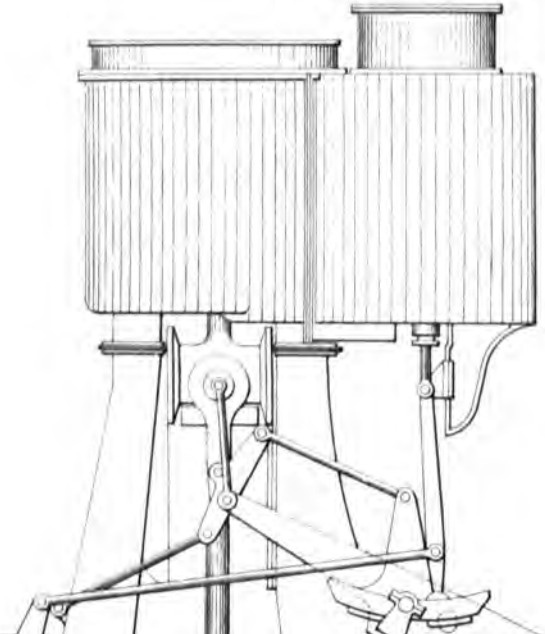
Mr. F. C. MARSHALL said, he was of opinion that the paper was so distinctly analytical that it required a considerable amount of thought on the part of any gentleman who wished to take part in the discussion; it would be well therefore to adjourn it till the following meeting to be held in Sunderland on the 14th of March, 1888.

This suggestion was agreed to, and the business of the meeting then concluded.

To illustrate Mr. J.T. Milton's paper on "Slide Valve Gears."

KIRK'S GEAR.

Fig 21.



BRYCE DOUGLAS' GEAR.

Fig 23.

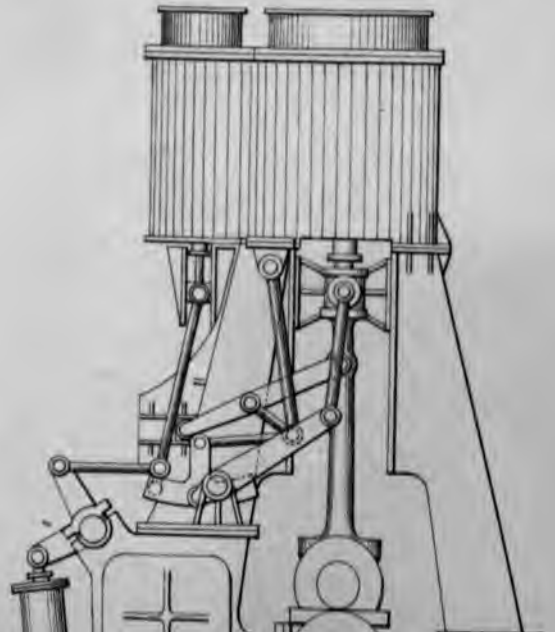


FIG. 3.

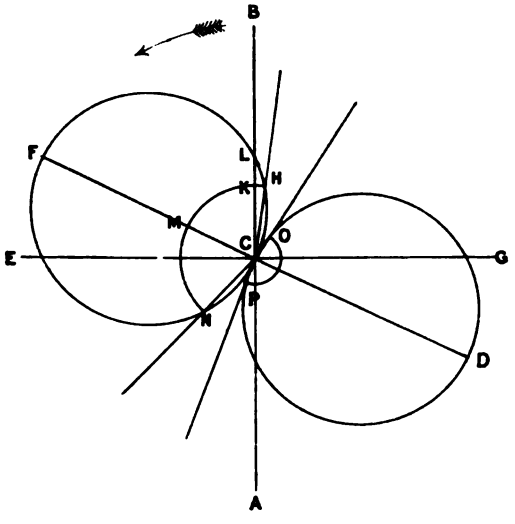


FIG. 4

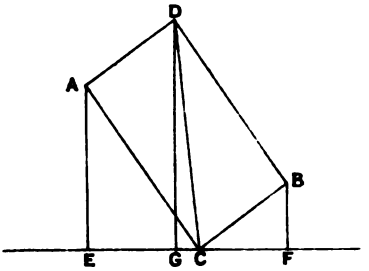


FIG. 7.

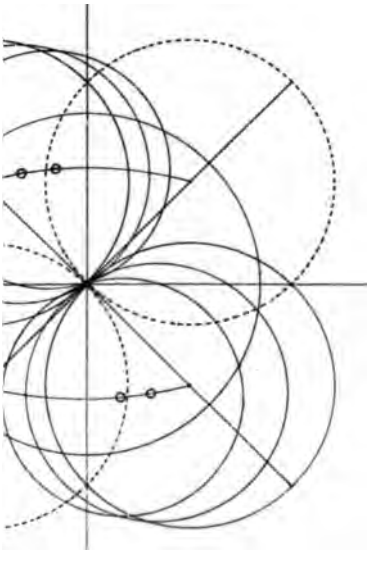
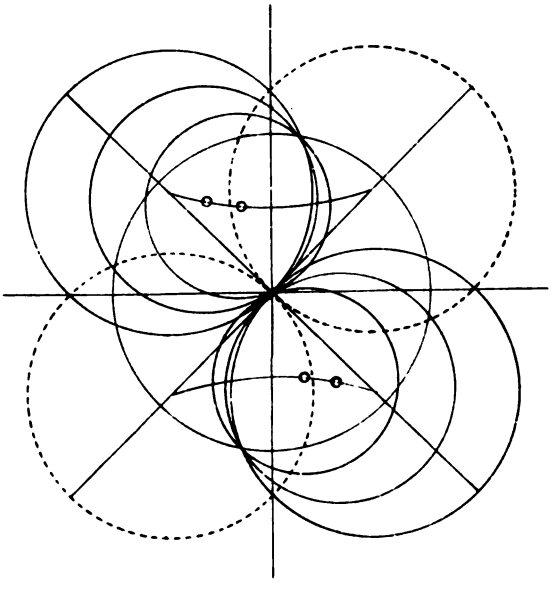


FIG. 8.



Ant. Reid, Lith. Newcastle

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887–88.

PROCEEDINGS.

EIGHTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LIBRARY, FAWCETT STREET, SUNDERLAND, ON WEDNESDAY EVENING, MARCH 14TH, 1888.

JOHN PRICE, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on February 22nd, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. M. Sandison and W. G. Spence to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Dunlop, William, 31, Hartington Street, Barrow-in-Furness.
Fenwick, James, 9, Park Road, South Shields.
Irwin, Thomas F., 2, Tower Chambers, Old Churchyard, Liverpool.
MacGregor, John, 51, Harrison Street, Barrow-in-Furness.
Prest, Stanley Faber, Chatsworth Terrace, Barrow-in-Furness.
Rickaby, A. A., Bloomfield Engine Works, Sunderland.

ASSOCIATE.

Charlton, W. A., St. Nicholas' Buildings, Newcastle.

GRADUATE.

Manford, Frank, 1, Osborne Terrace, Jesmond.

MARSHALL'S GEAR.

Fig. 27.

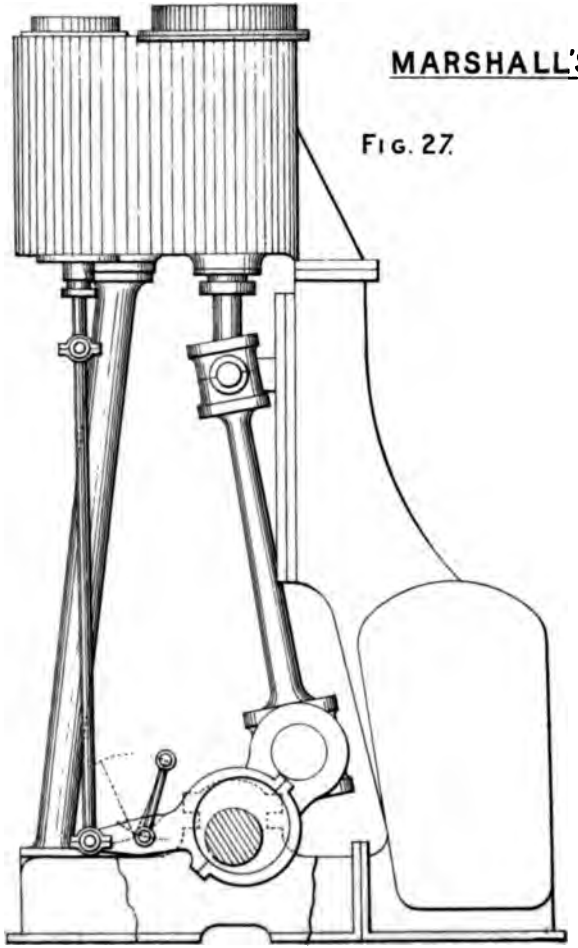
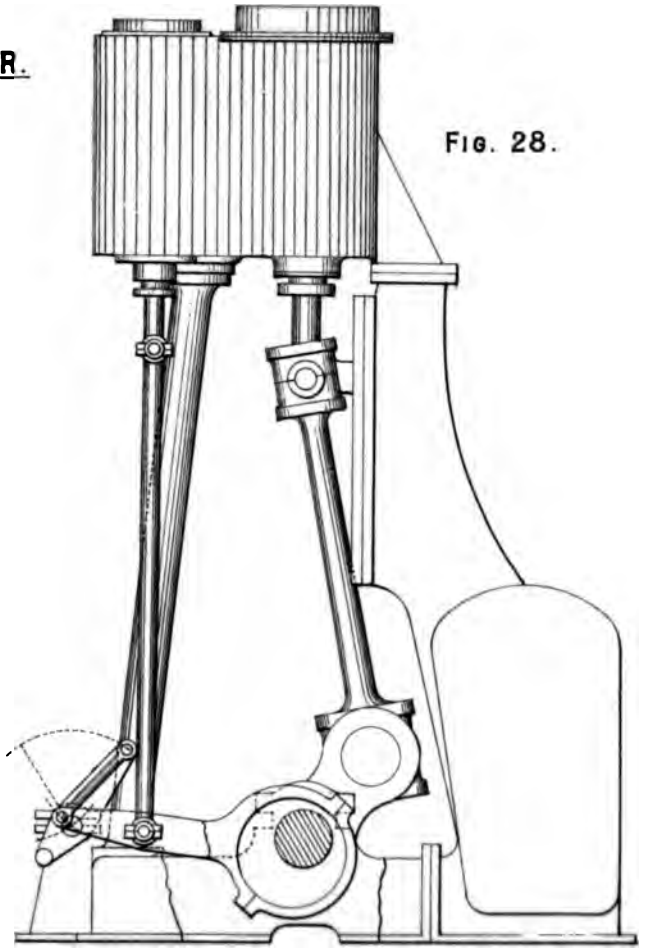


Fig. 28.



MARSHALL'S GEAR.

FIG. 27.

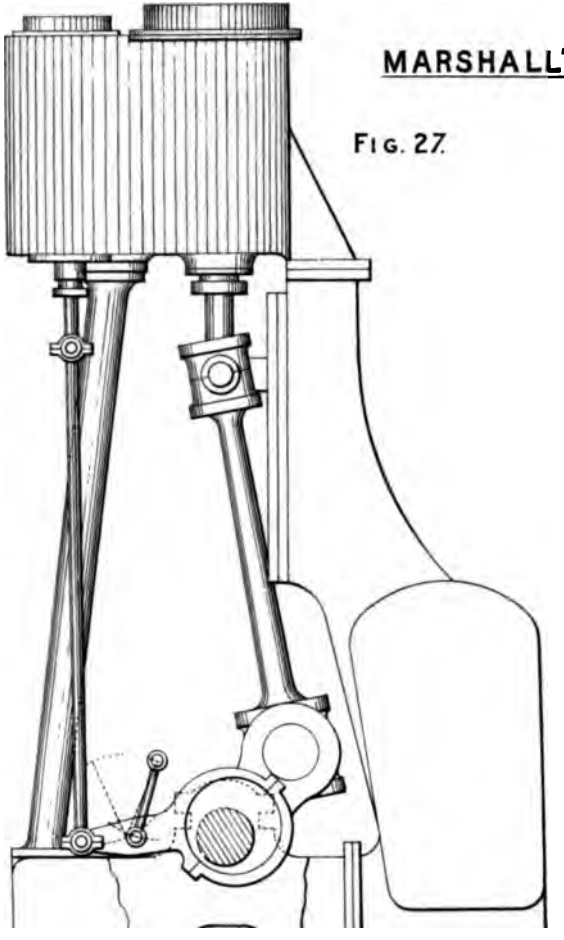
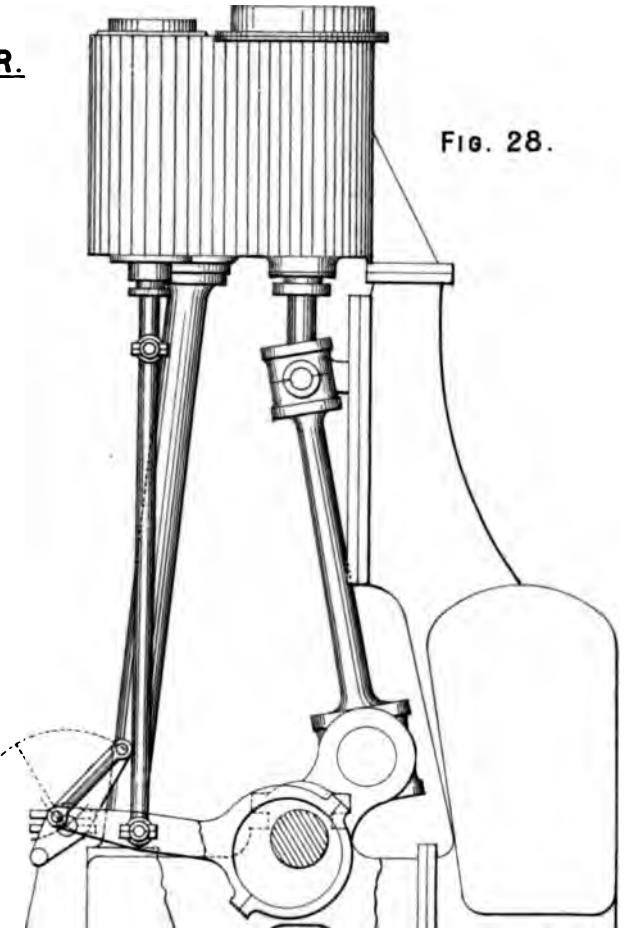


FIG. 28.



Mr. F. C. MARSHALL, with the view of opening the discussion, said he should like to make one or two remarks in connection with this paper, perhaps rather more of a personal and explanatory character than at all attempting to go into the questions that Mr. Milton had so ably raised as to the advantages and disadvantages of the various gears and the strains to which they were subject. He would only say, by the way, that he regretted to find that the diagrams of stresses had not been put up on the wall that night. Mr. Milton had alluded to all the systems of valve gear to which his (Mr. Marshall's) name was attached, and, perhaps, like the dog that had got a bad name, names got attached to things without, perhaps, having much right to them. He wanted distinctly to explain that any valve motion attached to his name was derived from the Hackworth motion. The only novelty he thought he had introduced, and for which he foolishly took out a patent, was for a swinging movement instead of the sliding movement which Mr. Hackworth invariably introduced. So far as he knew there was nothing of that kind in Mr. Hackworth's original machinery. It was, as Mr. Milton described, a simple angular slide in which the end of the eccentric rod or lever travelled, and by reversing the position of the guide allowed it to travel up in one way or another, and thus he got his motion. In order to avoid the difficulties of sliding surfaces, and making a gear that would simply be one of pins and bushes, working joints that would easily be repaired, turned, and bored, he (Mr. Marshall) adopted this motion. In thinking it out he found that the port opening at the top was very much less than the port opening at the bottom, and he introduced an additional steam port at the top end of the cylinder, and so got a large steam opening equal to that of the lower port; for he need not say that with great velocity of piston and of revolution it was not desirable to increase port openings or travel of valve to any greater extent than they possibly could help. Whether this was a new system or one similar to Mr. Hackworth's, fortunately it had been a very great success; and seeing it had many advantages, was so very easy to apply, and there was not a penny of royalty attached to it—it was free to the whole world to use—he was surprised so few engineers availed themselves of its advantages. With regard to the second form of it, Fig. 20, Plate XXIX., and Fig. 27, Plate XXXI., which he (Mr. Marshall) called the unfortunate form for the reasons explained by Mr. Milton, viz., in one of the movements on which there was the greatest motion, they had two-and-a-half times greater load than was needed, and that had sometimes led to disastrous results. This second motion had his name attached

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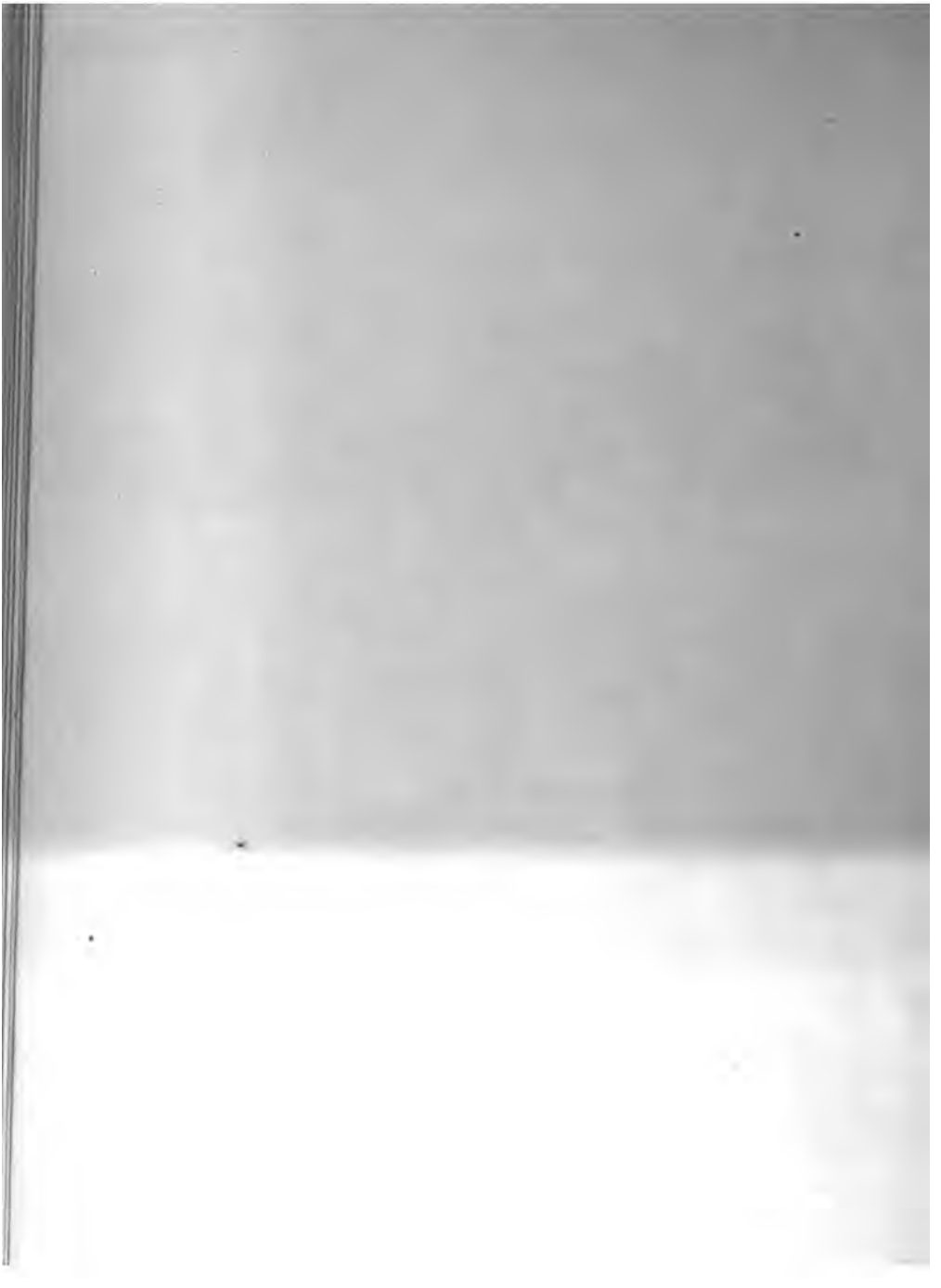


NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887–88.

PROCEEDINGS.

EIGHTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LIBRARY, FAWCETT STREET, SUNDERLAND, ON WEDNESDAY EVENING, MARCH 14TH, 1888.

JOHN PRICE, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on February 22nd, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. M. Sandison and W. G. Spence to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Dunlop, William, 31, Hartington Street, Barrow-in-Furness.
Fenwick, James, 9, Park Road, South Shields.
Irwin, Thomas F., 2, Tower Chambers, Old Churchyard, Liverpool.
MacGregor, John, 51, Harrison Street, Barrow-in-Furness.
Prest, Stanley Faber, Chatsworth Terrace, Barrow-in-Furness.
Rickaby, A. A., Bloomfield Engine Works, Sunderland.

ASSOCIATE.

Charlton, W. A., St. Nicholas' Buildings, Newcastle.

GRADUATE.

Manford, Frank, 1, Osborne Terrace, Jesmond.

The VICE-PRESIDENT said he was asked, on behalf of the Presi whom he regretted to say was detained in London, to call the atte of the Members to the Report of the Reading-Room Committee had been laid before the Council. The Committee recommends (1) a Reading-Room and Library for the benefit of the Institution shou established in Newcastle-upon-Tyne. (2) That in order to defra preliminary cost of furnishing, etc., which will amount to about £1 donation of £1 1s. be solicited from all Members who pay an a subscription of £2 2s., and from the Associates; and that, in ord defray the annual cost of maintenance of the Reading-Room, etc., will amount to about £150, the subscription of those Members wh half-a-guinea per annum shall be raised to one guinea, and that Graduates to half-a-guinea. Their attention was called to these re now merely as an informal communication. No action would no taken as they would come up at the Closing Business Meeting session. He was desired to state that with regard to the increase half-a-guinea subscription, the condition of the funds of the Instit was such that in all probability, whether the reading-room scheme carried out or not, these subscriptions would require to be incr The details of the annual income and expenditure, with the conti expenses of the reading-room, showed there would be an annual of about £190, which they would have to face in case they di agree to raise the subscription.

The discussion upon the paper on "Slide Valve Gears," by Mr. Milton, was proceeded with and adjourned. Mr. G. W. Sivew then read a paper on "Stockless Anchors and Fittings," followed discussion, which was also adjourned.

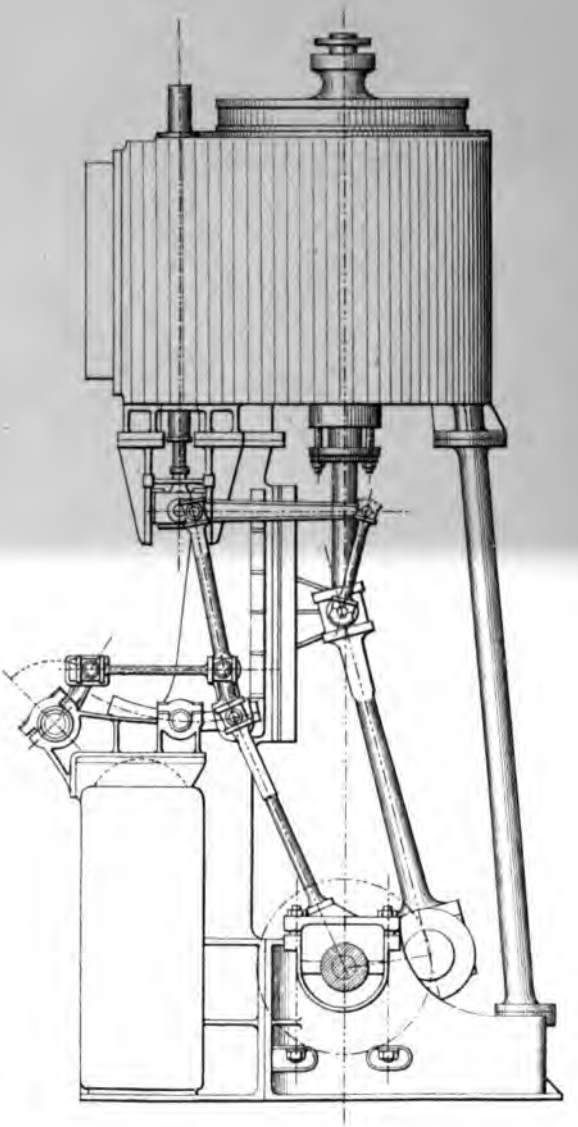
DISCUSSION ON SLIDE VALVE GEARS.

The SECRETARY said he had received a communication from Mr. Weir (of Messrs. Ramage & Ferguson, of Leith), together with a working model of the valve gear alluded to in the Communication, and if it was the pleasure of the meeting he would read it before anyone rose to speak on the paper. ("Agreed.")

Mr. J. WEIR wrote:—I have read with pleasure the proof copy of Mr. Milton's paper on the subject of Valve Gears. I would remark, however, that *Engineering* of September 17th and October 8th, 1886, contain an interesting article on "Radial Valve Gear," treated in exactly the same way as Mr. Milton now does; in fact the motions of the very gears he mentions, viz., Hackworth's, Marshall's, and Joy's are severally investigated by the aid of the Zeuner diagram, "further, it is shown that all radial gears are kinematically one and the same gear although modified in detail to accomplish certain ends, and that their seemingly complex motions open up before the pass-key of the Zeuner diagrams, so that with the aid of the diagram a designer can handle the most complex of compound radial gears as easily as the simplest arrangement with fixed eccentric." It would have been more interesting to the members of the Institution and to engineers generally had it been allowable to discuss the merits or demerits of the several valve gears illustrated, as much can be said for some of them while equally much can be said against others; but this would obviously be out of place seeing no particular gear is brought forward in the paper. A very important requirement, in a valve gear for marine engines, not mentioned in the paper, is its readiness to adapt or lend itself to the general arrangement of the engine. The author of the article in *Engineering* already referred to, calls attention to the willingness of engineers of late to adopt new and apparently complicated forms of mechanism for imparting motion to the distribution valves of the steam engine; but the secret of this is to be found more in their adaptability to the arrangement of engine than to the theoretically perfect results which are aimed at and which are more or less accomplished. My more immediate

object in addressing this to the Institution is to bring before the members, a valve gear not mentioned by Mr. Milton, which fulfils all the conditions laid down by him as essential for marine engines, with the further qualification laid down by myself, viz., its adaptability to general arrangement. I have no personal object in view in doing this, the valve gear is not patented like those described in the paper, although some of them have very slender claims to be called patent, indeed, if careful investigation were made, would be found to be entirely invalid. I submit a model of the valve gear for the inspection of members. The model itself may require some apology, it is rough and was made in a hurry to illustrate the gear to the owners of two steamships which my employers (Messrs. Ramage & Ferguson) had contracted for. It is to a 3 inch scale, and is arranged for the high-pressure engine, steam being admitted to the inside edge of the valve; for the other engines, where steam is admitted at the outside edges of the valves, the valve spindle is beyond the centre of the slide connecting rod. Those who are familiar with Zeuner's treatise will at once identify the model as being practically the gear described therein as Waldegg's. In its present form it is known as the "Walschaert Valve Gear," and is largely employed by Continental locomotive engineers, and has been fitted by English locomotive builders at the request of their foreign customers. I cannot find any trace of it being employed for locomotives in this country. The gear is of the compound type, the valve receiving its motion partly from the piston rod and partly from a single eccentric placed at right angles to its line of motion: the eccentric may be close up to the side of the crank, or outside of the bearing next the crank—in other words, the piston rod moves the valve through its external lap and lead, the eccentric giving the opening to steam. As will be seen from the model, the gear gives constant lead at all grades of expansions, or can be set otherwise in the same way as Mr. Milton describes for Marshall's gear. There is a difference in amount of opening at top to opening at bottom, but not to such an extent as to necessitate an extra port on the top. The reversing is accomplished by moving the slide connecting rod to the opposite end of the radius link. The distribution of steam is exactly the same at both ends of the cylinder, or may be varied at will. The motions of the gear can be investigated and analysed by the aid of the Zeuner diagram in the way Mr. Milton describes for the other gears. In Zeuner's treatise a theoretical diagram and description is given. I had hoped to supplement this by the actual diagram, but I have not had the time at my disposal. The obliquity of the rods play a most important part in this valve gear in controlling the movements of the valve. In

To illustrate M



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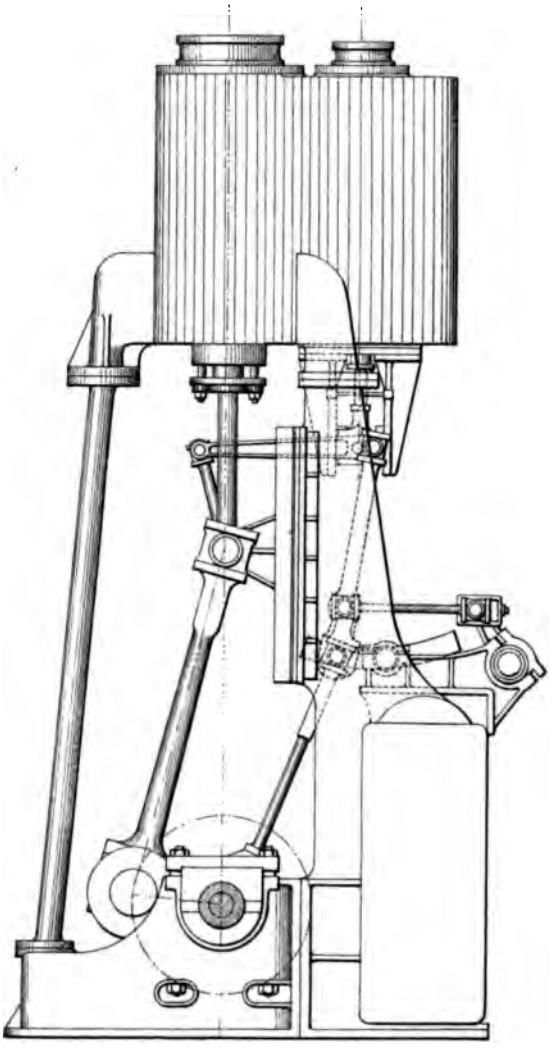

this gear it is quite correct to speak of the dwelling action of the valve, as can at once be noticed on the model, but more clearly by comparing elliptical diagrams in which the stroke of piston is abscissa and travel of valve ordinates. The history of the gear in so far as it has been applied to marine engines is brief. Two years ago my employers fitted it to a small engine; it was highly successful. The engine, with indicator diagrams, was subsequently illustrated in *Engineering*. At that time we were under the impression we were the only firm using the gear, but it turned out that Messrs. Denny & Co., Dumbarton, had also used it; quite recently I learned that Messrs. R. Napier & Sons had also fitted it. In view of bringing this before the Institution I placed myself in communication with these two firms. Mr. Kirk writes that he fitted the gear to the two iron-clads "Australia" and "Galatea" recently built by his firm for the British Government. Mr. Brock writes that three years ago he fitted the gear to three vessels for the British India Co.; from then till now he has also fitted about fifteen sets of engines ranging from 300 to 4,000 indicated horse-power. Mr. Brock has now on hands ten further sets, the power ranging from 400 to 6,000 indicated horse-power. My employers now fit the gear to the exclusion of every other gear, and up till now have fitted ten sets, all triple expansion engines ranging from 150 to 1,300 horse-power indicated. As I have already said, its history, so far as marine engines are concerned, has been brief, but none of the gears mentioned in the paper can show such a record in such a short space of time; which I think of itself is a sufficient guarantee of its utility for marine engine purposes. The strains are all direct, easily calculated, and in no case exceed the direct load on the valve to any appreciable extent; the number of working parts are more than in Marshall's or Hackworth's gear, but the summation of the goodness of any valve gear is not in its fewness of working parts, more especially when those parts are not subject to any severe strain. If there is nothing else to recommend the gear to manufacturers, there is its immunity from patent royalty, which for one of the gears mentioned in Mr. Milton's paper amounts to 10s. per nominal horse-power, a considerable sum for 6,000 indicated horses. I also send you an engine design with the gear fitted (see Plate XXXIII.); and as I have made this gear my special study, I will be only too glad to communicate to anyone the results of my experience with it.

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swinging link within his knowledge. Every one who had travelled in Belgium must be perfectly familiar with Walschaert's motion which had been described.

The VICE-PRESIDENT having failed to get the discussion on Mr. Milton's paper continued, and supposing that some interested members might be absent on account of the inclement state of the weather, said he could scarcely ask Mr. Milton to reply as he had got nothing to reply to. In his opinion, the subject was far too interesting to engineers to be put to one side by such a very brief discussion, and he scarcely thought it was fair to Mr. Milton and his elaborate paper to allow it to lapse.

Mr. G. W. SIVEWRIGHT said, that two gentlemen from Hartlepool were to have been present to discuss the valve motion, but possibly the stormy weather might have kept them away. He was ready to propose that the discussion should be adjourned.

Mr. R. THOMPSON seconded the motion that the discussion be adjourned till next meeting.

The VICE-PRESIDENT having put it to the meeting declared the discussion adjourned. He took this opportunity of stating that within his recollection, and it must also be within their knowledge, ever since the introduction of the Hackworth motion, which was, if not the first, at anyrate a very important attempt to deal scientifically with the action of the valve, it had been to a large extent the foundation upon which all other important successful actions had been founded. They had heard what had fallen from Mr. Marshall, and they could not but admire the frank acknowledgment which a man of his ability and experience had borne to Mr. Hackworth's meritorious inventions. He thought they owed a debt of gratitude to that ingenious engineer, John Wesley Hackworth, and that they ought to make that acknowledgment fully and frankly. Very few of the men who had meddled with this subsidiary question had received due acknowledgment; but even at this late period of the day he felt sure he would be expressing their views when he said that they acknowledged in a frank and unquestioning manner the very meritorious contribution to the steam engine by Mr. Hackworth's gear.

STOCKLESS ANCHORS AND FITTINGS.

By G. W. SIVEWRIGHT, M.I.N.A.

[Read before the Institution on March 14th, 1888.]

The anchor best known to the present generation of sailors is the common fluked anchor with stock; it appears to have done its work fairly well in holding moderate sized vessels, but when the dimensions of vessels increased, thus presenting larger forms to the action of the elements, the holding power of these anchors was found insufficient; and cases have been known, where, with this type of anchor, the stocks have been badly bent or broken, thus rendering the anchor practically useless; this being most likely to occur when the anchor is on a rocky bottom.

Another objectionable feature in using stocked anchors is the custom of having to carry them suspended from the hawse pipes when the vessel is entering a river; for when suspended in this manner the fluke and stock project so far from the bow, that, in the event of a collision, the fluke has often penetrated into the bows of both vessels, doing considerably more damage than that caused by colliding.

Probably one of the earliest attempts to make an anchor with more holding power, was the introduction of "Martin's" double fluked anchor with the stock at the end of the shank. (Fig. 1, Plate XXXIV.) This anchor possessed several advantages over the common type, and appears to have been brought into general use; it being so easy to stow away on the forecastle deck was another consideration in its favour; but, whether through the bad distribution of weight or insufficient tripping head, its holding power was not to be relied upon under all conditions, and after some years of use this design of anchor was abandoned.

As vessels increased in size, the lowering of anchors from the forecastle head proved a tedious task, and should the vessel be riding in an open roadstead, subject to a heavy range of sea, the fishing of the anchor back on to the forecastle deck was not only a difficult but a dangerous operation.

This trouble of working anchors had been brought so prominently from time to time before the public, that in 1877 Messrs. Scott & Riddell hit upon the idea of drawing up the shank of the stockless type of anchor into the hawse pipes, thus dispensing with all catting and fishing of anchors.

Shipowners, in adopting this plan, readily saw the advantage to be gained, and the arrangement has found such favour and has also given such a stimulus to anchor makers, that during the last few years we have had quite a number of different designs of stockless anchors put upon the market, and all made so that the shank can be housed into the hawse pipes.

The idea of a stockless anchor is not new, as many years ago one Robert Hawkins patented a double fluked anchor, but by referring to sketch, Fig. 2, Plate XXXIV., it will be seen that the head is deficient in tripping power, and from other faults in the design it was not brought into general use.

After this several designs of mushroom anchors were brought before the public, one of which is illustrated in Fig. 3, Plate XXXIV. These anchors had so little holding power that probably they were used only experimentally.

The double fluked stockless anchors, that are now in use, display a considerable amount of skill and ingenuity in their design, and special attention appears to have been given to the tripping power, a most essential point in this type of anchor.

It will be noticed in the design of "Parkes'," "Baxter's," and "Hall's" patents, that the tripping power is at the centre of the head; and a special feature in Hall's design is the crosshead, which would prevent the head of the anchor leaving the shank supposing the through pin to be broken.

In the design of "Smith's" anchor, the tripping power is at the head of the flukes at each side instead of in the centre. It is claimed by this arrangement, that more area of ground is covered, thus giving the anchor a better chance of tripping on a rocky or uneven bottom. There are a large number of anchors of this type in use, and they appear to have done their work very well.

The anchor known as "Tyzack's" patent, has a novel arrangement at the head whereby three flukes are brought into use; although this anchor (on account of the centre fluke) would not house quite so close to the vessel's side as some of the other anchors, yet there can be no doubt that the addition of the third fluke would be of great importance supposing the anchor to be down on a thin muddy bottom.

There are many other designs of stockless anchors, but it would take up too much of the time of this meeting to describe them all; and the writer feels that it would be out of place for him, on account of the general character of this paper, to particularise the superior qualities of certain anchors to the detriment of others. He thinks, however, that the members of this Institution will have no difficulty, with the assistance of the numerous diagrams and models in connection with this paper, to form an individual opinion as to the merits of any particular anchor.

The Admiralty have experimented with double fluked stockless anchors in competition with anchors of other designs, and from the results of these experiments they appear to favour (in preference to the stockless type) a double fluked anchor with a small stock at the end of the shank, and this anchor is known as the "Improved Martin's Patent." (Fig. 4, Plate XXXIV.)

On comparing the two Martin anchors, viz., the one made in 1854, and the one in use at the present time, it will be seen that the improved anchor is fitted with a tripping head; now if this type of anchor was unsatisfactory in the first patent, and the addition of a tripping head has put it right in the second design, the writer ventures the opinion that it proves double fluked stockless anchors, with good tripping heads, to have important qualities, though they may not be fitted with stocks.

It is questionable whether the small stock on the shank of the Martin anchor would prevent it from gyrating, if it had any tendency to do so, and the writer thinks if any benefit is derived from this stock, it is owing to the increased weight it gives to the shank.

The weight of the shank of stockless anchors might be increased without spoiling the design, as shown in the sketch of the "Proposed" anchor, Plate XXXIV., and by thus increasing the weight at the top end, it would assist to keep the shank in a more horizontal position, especially when the vessel was riding with a short length of cable.

But whatever design of anchor is accepted for general use, it would be asking too much to expect it to be perfection in every respect, and in deciding upon an anchor, the all-round advantages to be gained should be well considered.

From a careful study of this question, backed up by experience gained from a number of exhaustive trials made at sea with different types of anchors, the writer has every confidence in recommending the use of stockless anchors housing into hawse pipes, and considers that this plan is the best all-round arrangement now in use.

By adopting this system of housing anchors, all cranes, davits, and

other gear are dispensed with, thus saving the renewals of blocks, ro falls, etc., attendant upon the old plan; it also gives a clear forecast head which is of great advantage whilst working the vessel in and out port.

The method of housing is simplicity itself. All that is require when commencing to hoist the anchor is to see that the windlass cabl holder brakes are screwed in and the pawls down. It is not necessary f any of the officers to be standing by the stem head to superintend th work, for when the head of the anchor is hauled close home to the side the vessel it acts as a brake, stopping the windlass without doing a damage.

The time occupied in dropping these anchors and hoisting in position again is only a few minutes, and two of the crew only a required to carry out this operation.

As the results of the writer's experience and observations, the followin recommendations are advised to be carried out in the fitting of stockle anchors housing into hawse pipes, viz. :—

It would very much assist hoisting operations if all sharp corners the head of the anchor, jaws of shackles, and heads of pins be carefull rounded off. If the shackle at the top is made a good long length it of great assistance to the shank when first entering the mouth of the pip as it helps to cant the shank from a vertical to a diagonal position.

Care should be taken in the design of hawse pipes, as it has bee found necessary to make them of increased diameter in comparison wit the ordinary design of hawse pipes. Should heavy anchors be used th pipes would require to be strengthened up on the outside with webs, an made thicker at the bottom. (Fig. 6, Plate XXXVI.) By still furthe increasing the diameter and making a recess at the mouth of the pipes it would be possible for the heads of several of the anchors shown o plans to be housed further home, but by doing this it considerabl increases the cost of the arrangement. (Figs. 7 and 8, Plate XXXVII.

Where the cables run over the top of the pipes, the metal covers shoul be increased in thickness at the after side to take the chafe off the cables and here it may be stated, that some owners prefer a roller at the head o the pipes to ease this chafing.

An important consideration in the arrangement is to see that a goo lead of pipe is obtained so that when the anchor is housed the flukes an head bear on all points against the shell plating. The most suitabl angle to attain this is found to be 38 degrees from the perpendicular.

As a considerable amount of vibration comes upon the mouth of th

Ring

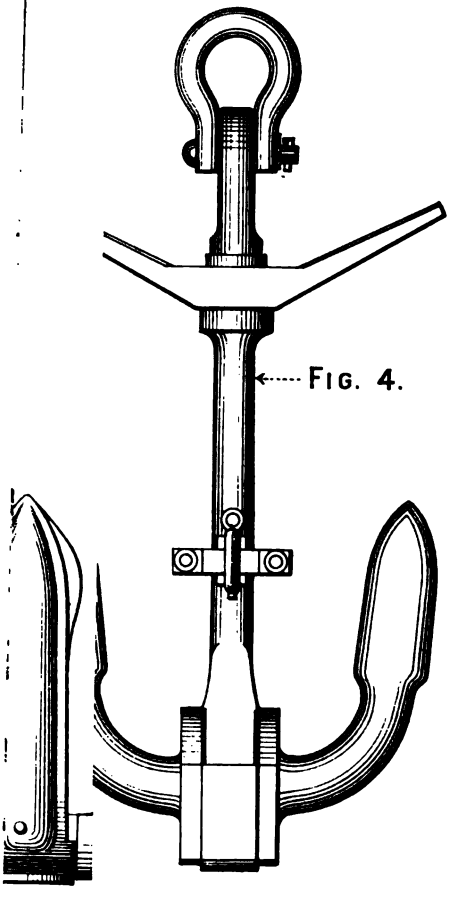
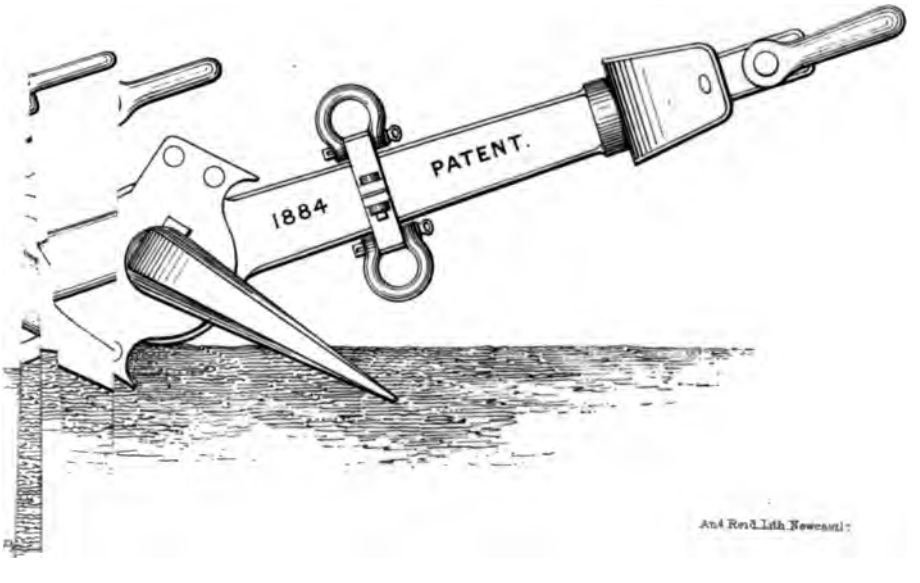


FIG. 4.

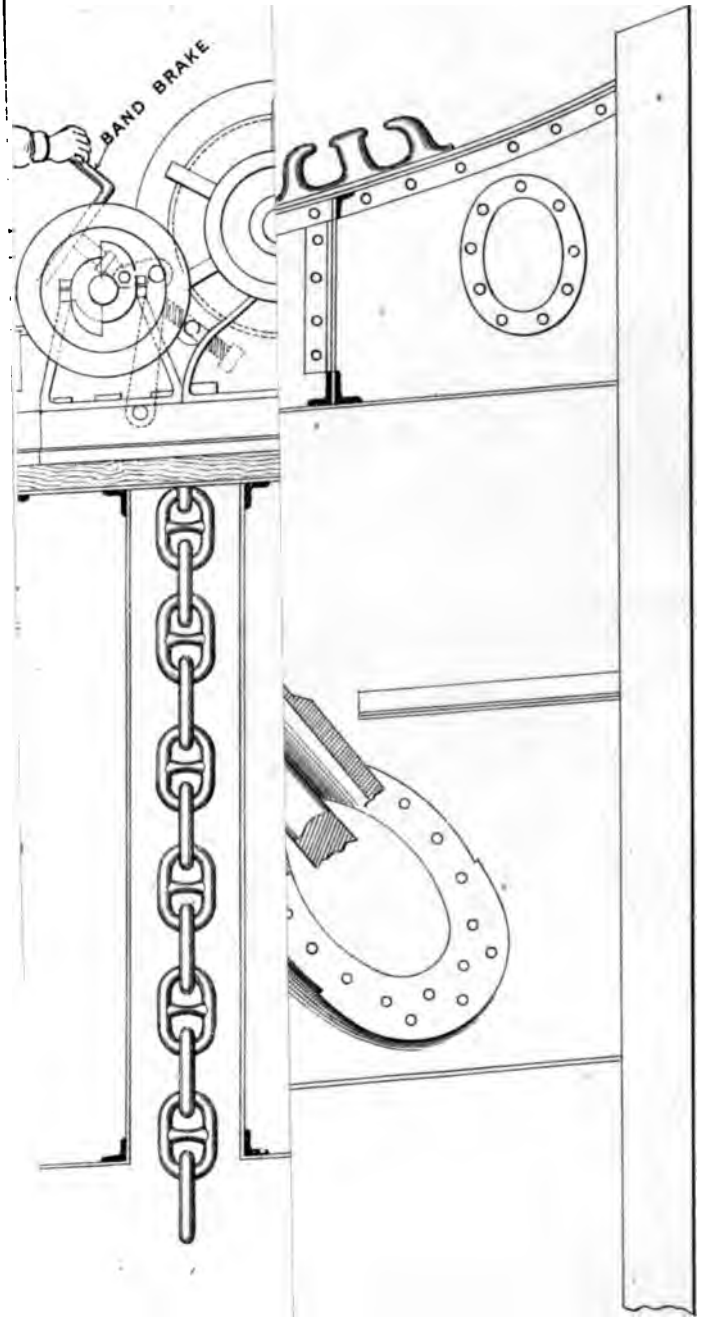


And Reid Lith Newcastle

ago Mr. Smith was at their works for some time inspecting bridges for the Russian Government; they were then making Martin's anchors, and he thought it very likely Mr. Smith caught the idea there and worked it out, and of all the stockless anchors he thought Mr. Smith's was the best; but the question was, was the stockless anchor a safe anchor? for it was all very well for it to be nice and handy and look well in the hawse pipe; but when the ship had to depend upon the anchor in a storm, what mattered its looking well if it could not be depended upon? He held that a stockless anchor was not a safe anchor, and in proof of the fact would refer to the trials made by the English Admiralty in 1885 (see page 273). These were a series of trials conducted by Government officers, and the anchors represented were the Martin Improved Anchor and Mr. Smith's anchor.

Mr. SIVEWRIGHT—Would you give the weights of the anchors?

Mr. CHARLTON—The Improved Martin's was 60 cwt., but he did not know the weights of the other anchors. The trials were conducted by the Admiralty officials in their own way. He believed various patentees were represented. They were informed of the date of the trials, but, unfortunately, the Admiralty refused to give anyone a copy of the reports made by officers who conducted the trials. They said, that was their business and not the business of the public; but he thought Mr. Smith would bear him out that the results of the trials, as far as they might judge, were very much in favour of the anchors with stocks. If he was correctly informed, and he thought he was, the anchors were tested against an Admiralty anchor with a single fluke and long stock. It was embedded in the ground at a certain distance, a flagstaff was put down where the anchor was bedded, the other anchors were dropped down a certain distance from the Admiralty anchor, and block and tackle arranged between them. The Improved Martin's anchor was dropped and took hold at 7 feet, then dragged the Admiralty anchor 123 feet without moving an inch. The next was the Inglefield anchor, originally sent to the dockyard *without a stock*; but whether or not they thought the stockless anchor would not be so successful he could not say, but before the trials it was fitted *with a stock*. Inglefield's took hold at 10 feet, and dragged the Admiralty anchor 116 feet. Smith's anchor took hold at 14 feet, and fell foul of a wooden pile: of course that added very much to its holding power, and it dragged the Admiralty anchor 61 feet. At the second trial, Mr. Smith's anchor dragged the Admiralty anchor 35 feet, but when the full strain was put upon the anchor, Mr. Smith's anchor was dragged 112 feet, and actually came out of the ground, showing that when a very heavy strain was put upon the



And Reid Lith Newcastle.

To illustrate Mr E. Reynolds

REYNOLDS'S PATENT ANCHOR.

SECTION

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Proceedings N.E.C.I. of Es. 1887-88

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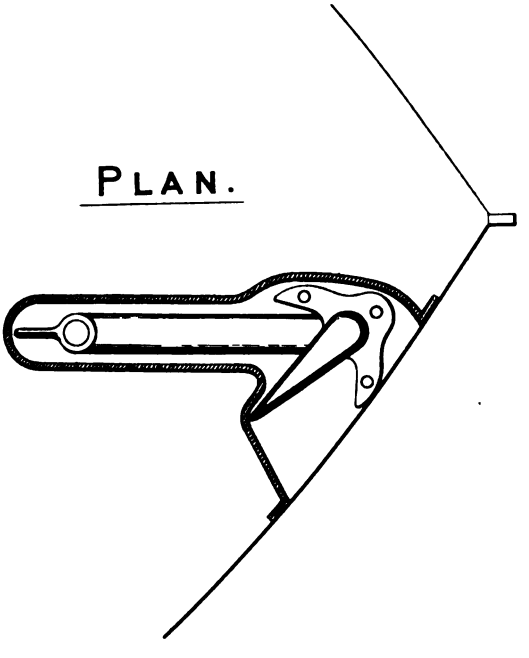
PLAN.



And Reid. Lith Newcast

hawse pipes, the shell plating should be increased in thickness at these parts, and the butts of the shell plating kept well clear of the mouth of the pipes.

To prevent the flukes of anchors from catching the landing edges, it has been suggested to double the shell plating for some distance down in the way of these pipes, but in actual practice this is not necessary; all that is required is to slightly chamfer the lower edges of the outside plating for about three strakes down inclusive of the sheer strake.

In addition to the usual compressor brakes, the fitting of band brakes to the windlass will be found of great advantage, especially when the vessel is entering or leaving port, as the anchors can be suspended from the windlass by these brakes only; and at a moment's notice, in the case of emergency, the anchors can be dropped by simply slackening the brakes without having to cast adrift any other gear.

In some of the first steamers supplied with stockless anchors housing into pipes, the ordinary deadnip cable compressors were fitted on forecastle deck, but on account of the quick speed at which the cables ran out in dropping the anchors, it was found in many cases that the jaws of these compressors were badly broken by the cables, and, as the result of this, very strong chain stoppers have been fitted in lieu of these compressors, and have proved to be of considerable value in holding the anchors when the windlass is required to be overhauled, or when the main cables are found necessary to moor the vessel in a streamway. (Fig. 9, Plate XXXV.)

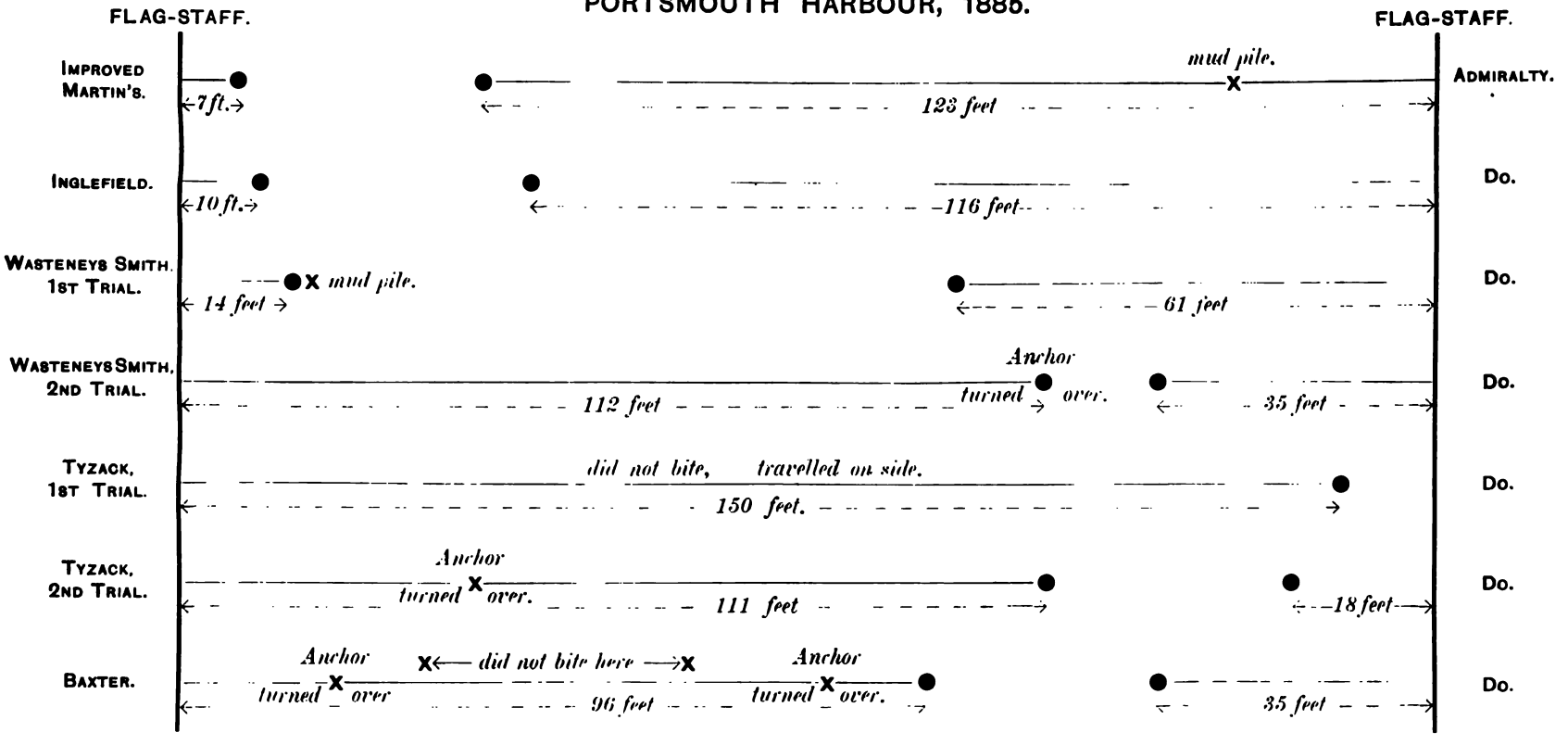
There are several other plans of housing stockless anchors into the bows of vessels, but the plan described in this paper has been carried out in a number of vessels built by the firm of Messrs. Edwd. Withy & Co. during the past four years; and, whilst simple in character, has been found not only economical, but very efficient in its working and to have given every satisfaction.

The writer expresses the hope that this paper may offer some inducement and encouragement to the further development of the use of stockless anchors, and although there must naturally exist a strong prejudice in favour of the common type of anchor, yet he feels, when a matter of this important character is taken up and discussed by the members of this Institution, that, as a natural consequence, the superior qualities of stockless anchors must in due time be appreciated by shipowners.

DISCUSSION.

Mr. H. CHARLTON said, not being a patentee of anchors himself, he perhaps had better open the discussion. Seeing several patentees present, he hoped they would follow and make the discussion worthy of this Institution. In the first place, he had to thank Mr. Sivewright for the very fair way in which he had put the merits and demerits of the various anchors before the meeting; but he did not agree with the conclusions he had come to. There he thought they had fair ground for discussion. It was something like thirty years since Mr. Martin, a Frenchman, came to Gateshead Iron Works to have his anchor manufactured. Of course the anchor then made, thirty or thirty-one years ago, was altogether different from the one before them. In fact, Mr. Tyzack's present anchor more resembled the original anchors, for Martin's original anchor had a "sector" or canting block something like what Mr. Tyzack's had, and which he called the third hook. For various reasons this anchor was not a success, as great difficulties were experienced in fixing the sector or canting block securely. The next anchor Mr. Martin brought out was something like the one shown; the shank having a large solid head. Now this had a very considerable sale for a large number of years, but the defect in the anchor was this: the flukes had only their own weight for forcing them into the ground, and this large head, when the anchor fell into strong heavy clay or hard ground, prevented the flukes going beyond a certain depth. That might be considered a defect. Referring to this second anchor, Mr. Sivewright says in his paper:—"This anchor possessed several advantages over the common type, and appears to have been brought into general use; it being so easy to stow away on the forecastle deck was another consideration in its favour; but whether through the bad distribution of weight, or insufficient tripping head, its holding power was not to be relied upon under all conditions, and after some years of use this design of anchor was abandoned." He might inform the meeting and Mr. Sivewright at the same time that this form of anchor was not abandoned, as some people still asked for them, and only that day they had shipped four of these anchors from their works to Glasgow, and, in fact, they were making them constantly. The Trinity House have had several lately and bought a large number for mooring purposes. The mistake was one that Mr. Sivewright was very liable to fall into. But the real question before the meeting was the value of the stockless anchor as against the anchor with the stock. Of the stockless anchors he saw before him, he believed Mr. Smith's was the first introduced with double flukes. About twenty years

DIAGRAM SHOWING RESULTS OF ENGLISH GOVERNMENT TRIALS IN PORTSMOUTH HARBOUR, 1885.



The Improved Martin's Anchor not only shows the best result in actual figures, but in addition had to pull the Admiralty Pattern Anchor, to which it was opposed, through a sunken mud pile—an extra severe and unexpected test, to which none of the other competing Anchors were subjected.

ago Mr. Smith was at their works for some time inspecting bridges for the Russian Government; they were then making Martin's anchors, and he thought it very likely Mr. Smith caught the idea there and worked it out, and of all the stockless anchors he thought Mr. Smith's was the best; but the question was, was the stockless anchor a safe anchor? for it was all very well for it to be nice and handy and look well in the hawse pipe; but when the ship had to depend upon the anchor in a storm, what mattered its looking well if it could not be depended upon? He held that a stockless anchor was not a safe anchor, and in proof of the fact would refer to the trials made by the English Admiralty in 1885 (see page 273). These were a series of trials conducted by Government officers, and the anchors represented were the Martin Improved Anchor and Mr. Smith's anchor.

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Mr. CHARLTON—The Improved Martin's was 60 cwt., but he did not know the weights of the other anchors. The trials were conducted by the Admiralty officials in their own way. He believed various patentees were represented. They were informed of the date of the trials, but, unfortunately, the Admiralty refused to give anyone a copy of the reports made by officers who conducted the trials. They said, that was their business and not the business of the public; but he thought Mr. Smith would bear him out that the results of the trials, as far as they might judge, were very much in favour of the anchors with stocks. If he was correctly informed, and he thought he was, the anchors were tested against an Admiralty anchor with a single fluke and long stock. It was embedded in the ground at a certain distance, a flagstaff was put down where the anchor was bedded, the other anchors were dropped down a certain distance from the Admiralty anchor, and block and tackle arranged between them. The Improved Martin's anchor was dropped and took hold at 7 feet, then dragged the Admiralty anchor 123 feet without moving an inch. The next was the Inglefield anchor, originally sent to the dockyard *without a stock*; but whether or not they thought the stockless anchor would not be so successful he could not say, but before the trials it was fitted *with a stock*. Inglefield's took hold at 10 feet, and dragged the Admiralty anchor 116 feet. Smith's anchor took hold at 14 feet, and fell foul of a wooden pile; of course that added very much to its holding power, and it dragged the Admiralty anchor 61 feet. At the second trial, Mr. Smith's anchor dragged the Admiralty anchor 35 feet, but when the full strain was put upon the anchor, Mr. Smith's anchor was dragged 112 feet, and actually came out of the ground, showing that when a very heavy strain was put upon the

anchor, without a stock to keep it from gyrating, it was very apt to turn over, and that, he believed, happened in the second trial of Mr. Smith's anchor. Mr. Tyzack's anchor that was tested, he ought to explain, was not the one represented on the table. The one tried by the Admiralty was a single fluked anchor, and, therefore, he thought it was not fair to speak of Mr. Tyzack's, now shown, as it was not the one that was tried, so he would say nothing about it. The next was Baxter's anchor; it pulled the Admiralty anchor 35 feet, but, after a heavy strain, Baxter's anchor was dragged 96 feet, and afterwards came out of the ground the same way as the other stockless anchors. One of the scientific papers connected with the army and navy stated at the time:—"The Dockyard authorities at Portsmouth have completed a protracted series of trials of patent anchors, which were tried weight for weight against the Admiralty pattern. The tests, which were carried out under the superintendence of the Captain of the Steam Reserve, the Staff Captain of the Yard, and the Chief Constructor, consisted of dropping the anchors into the harbour mud at low tide and pulling upon them from a lighter, the one which resisted the greatest strain thereby demonstrating its superiority. The Improved Martin was found to be in every way superior." Mr. Sivewright had asked him to give some idea of the weights of the various anchors. He did not know the weight of the Admiralty anchor against which all the others were tried, but he knew the Martin was 60 cwt., and Smith's a 40 cwt. anchor. There was a report made, and by some means certain persons may have got a portion of it, although not at liberty to make it public, except this one point:—"The anchors tested varied from 14 cwt. to 60 cwt. With regard to stockless anchors, whenever more than ordinary force was applied the anchors showed invariably a tendency to gyrate upon the ground, and, finally, turned out with the flukes uppermost. Where the ground was hard the anchor skidded along the ground and was useless." He did not know the weight of the Admiralty anchor. These were the results of the trials at Portsmouth. He thought the best thing to satisfy the public and a scientific Institution like this was to know how the Admiralty had acted. The trials had resulted in the Admiralty ordering a very large number of Improved Martin's anchors. Messrs. Hawks, Crawshay, & Sons, had supplied a 6½ ton Martin's anchor for the "Victoria," and two the same weight for the "Sanspareil." They had had other orders besides, some from 135 cwt. down to 1 cwt. They had executed orders for about 100 tons for the Admiralty alone; and so much were they in favour of the Improved Martin, that a large number of the old Martin anchors they had in the dockyard had

been altered to the new patent, and that, he thought, was the best proof that the Admiralty were satisfied. They could not get a copy of the report, but they had the results, namely, that the Admiralty had adopted the Martin to a large extent, and that they did not believe in the efficiency of stockless anchors. The Chinese, Spanish, and other governments had followed their example, and this, in his opinion, was the best argument that he could use. The stock not only steadied the anchor and prevented gyrating, but increased the holding powers. He (Mr. Charlton) simply wanted to open the debate and give the facts as far as he could, having been connected with the anchor trade more or less for a considerable time.

The VICE-PRESIDENT was sure the meeting would feel they were indebted to Mr. Charlton for taking the trouble to come there and give so clear and lucid an explanation of his connection with the Martin anchor. It must have been highly interesting to everyone.

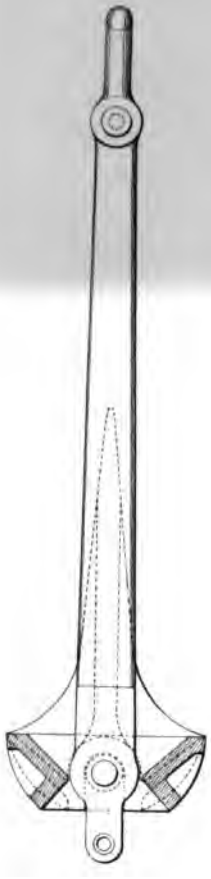
Mr. REYNOLDS could not speak with any such experience as would enable him to add to the admirable remarks they had heard, nevertheless he had considerable knowledge of the subject. In regard to what was called the Martin anchor; when several years ago an agent called to offer the invention to his company he declined to accept it or to recognise any such patent, because since 1855 he had possessed engravings of the very same thing, patented by Johnson for David, of Havre. The only patent he could find in the name of Martin was dated 1864, and has no essential points of difference.

Mr. CHARLTON thought he said over thirty years ago. The patentee was a German whose name he had forgotten, but he came to the works in 1855.

Mr. REYNOLDS said, very shortly after the important trials at Portsmouth to which Mr. Charlton referred, in consequence of communications from the Admiralty he (Mr. Reynolds) visited Chatham and saw his genial friend, Mr. Warren, the chief constructor, who showed him various anchors, amongst others that of Mr. Smith. That appeared to him almost an ideal anchor, for without undue weight it was practicable to place the two flukes so far apart that they would have a very good hold in the ground. The result was that instead of offering to do anything for the Admiralty he went home and had a model made (which he produced), which is illustrated on Plate XXXVIII., for which he had since taken out a patent. That was made not to show precise detail, but to illustrate the principle. As he understood the Martin anchor originally made, there was merely a slight nib in a recess that to an engineer would appear to be a weak bit to bear the strain of wrenching out of the hard ground.

To illustrate Mr E. Reynolds

REYNOLDS'S PATENT ANCHOR.



SECTION

ELEVATION

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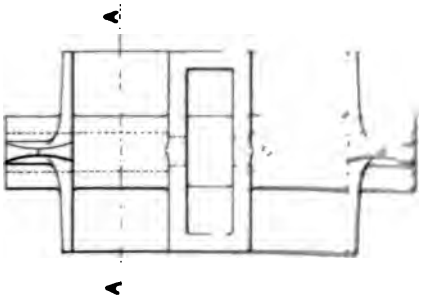
n Mr. Sivewright's paper.



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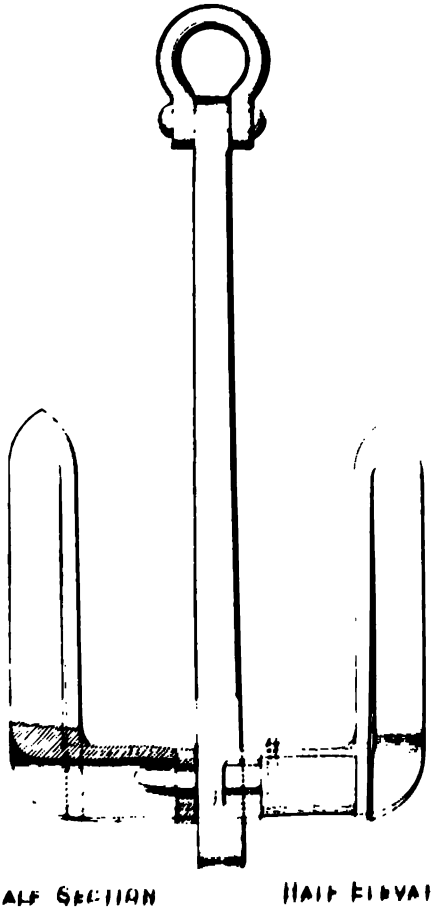


HALF SECTION HALF ELEVATION

Mr. CHARLTON—They were tested by Lloyd's with the full strength.

Mr. REYNOLDS said, there appeared to him a similar slight disadvantage in the Smith anchor. For that reason he made this model. He threw out the suggestion that the flukes might be made like T pieces, so that there would be as good a chance of keeping the bed as a single fluked anchor. In case of partial turning over, another idea was that a more easily forged shank could be made, not like Messrs. Hall & Verity's, with a crosshead, but a plain shank fitted in between cheeks, and there was also a double abutment for wrenching it out of the ground so that the connecting pin bore no strain except the same tractive force as the shackle pin. But there was another point to which he desired to call attention. Mr. Warren, then chief constructor at Portsmouth, in speaking to him about the tests, said that certain makers of steel anchors had objected to a very high fall test; but he thought most people would hardly trust any anchor that would not bear a considerable fall, and although steel castings could now be obtained having a very high degree of perfection, still he thought it would be admitted that no casting was quite so well fitted to bear shocks as forgings, so they should be specially tested by falling. They could not avoid the risk of falling unchecked through the water, and it occurred to him that the canting fins might be made to give sufficient surface to limit the rate of fall through the water. For example, the anchor illustrated on Plate XXXVIII. gives a surface endwise of 24 square feet, which, if taken at a scale, makes the anchor weigh 95 cwt. or only 4 cwt. to the square foot; this would only allow of a velocity through the water due to a fall of about 7 feet high. Hence it was easy to obtain data for a proper comparative fall for proving such anchors.

The VICE-PRESIDENT said, he remembered that during his boyhood, in this very port of Sunderland, the stocks of the ordinary collier anchor and first-class ship anchor were most frequently made of wood, American elm, strongly clamped, and firmly bound with iron hoops, so that it should stand the shock of falling, and also the drag on uncertain ground. Ships were seldom sent to sea with a stock like that exhibited as an example of the stock anchor, except small vessels. The stocks of East Indiamen built in this port were just such as he had mentioned, with this alteration, that instead of being built with rectangular sections at each side of the anchor shank, they were worked down to a round form, sometimes made of teak, and closely bound with iron, and a very strong and serviceable anchor it was.

Mr. WASTENEYS SMITH (by invitation) said, they would all agree that his name had been associated with stockless anchors for a great many years. He thought the matter of anchors was a more important one than it generally was taken to be, but he found at the present moment that prices ruled the day, and that an anchor was taken very often in these hard times more for its low price than value. Still, he thought, the number of orders he had received for his anchor while it had been before the public, and the great number he had made, should be a sufficient recommendation for the stockless system. He had made now nearly 1,300; and, he might fairly assert, that selling the first 500 or 600 of them at the high price he had formerly to get, showed stockless anchors were largely appreciated. He had not been in the position of Messrs. Hawks, Crawshay, & Sons, which eminent firm his friend, Mr. Charlton, represented, nor of being able to manage the Government. He supplied anchors to the Government so long as ten years ago. He lent them a 50 cwt. anchor at first for two years, at considerable outlay to himself. They took it away to sea, and so highly was it approved of, that they ordered others and paid for the one on trial. He then fitted out fourteen ships in the navy from the largest class afloat, and believed they were perfectly successful in every respect. He heard of those trials, to which Mr. Charlton alluded and thought so much of, but had not been asked to supply any anchors for competition, and, of course, thought they were perfectly satisfied with his, for, better than any specific trials, they had had many anchors in use for five or six years, sufficiently long to settle their merits. After most of the trials had been completed, he was suddenly called upon to send an anchor, and was put to the expense of making one of 48 cwt. It had to be made with the utmost speed, and at a great disadvantage, but was, however, eventually sent in time. He (Mr. Smith) went down and witnessed the trials. He knew a great deal, perhaps more than should be told there. The only relative trials were made at Spithead, and in those trials the only anchor that stood the test was his 48 cwt. anchor, against Martin's 61 cwt. anchor, the Admiralty anchor, and others. Some, he would admit, were lighter than his own, but the only anchor to hold eventually was his. The anchors were afterwards put down in the mud within the harbour and tried. It was subsequently found that his had got hold of some piles, for it dragged the lighter, 250 tons dead-weight, 3 feet on the mud. He (Mr. Smith) had come away from the trials with an idea that the anchor had got hold of something more than mud. He could not attend until the day after that appointed for the second trials. His anchor by that time had lain

five tides on the mud, which had therefore got pretty consolidated round the anchor. The trials on the mud were made by the two anchors being laid down at a distance of 30 fathoms apart, with sets of blocks and rope connecting them together, the two ends of the rope were led to two steam capstans on board a lighter, which lay on the mud midway between the anchors. It was obvious when the capstans were worked the anchors must move, and that the anchor with least holding power would advance most. After starting, and when the Admiralty anchor commenced to travel towards the stockless anchor, a remark was made that "it was no use trying this against the Admiralty anchor," and therefore the block was taken from the latter and secured to the bow of the lighter, and thus the strain was directly applied to the stockless anchor, compelling it to advance until the cable was at so sharp an angle as to turn the anchor on its side and pull it out of the ground. As this trial was not made with the Martin or other anchors, they being allowed to hold their own against the Admiralty anchor if they could, the purchase never having been moved so as to apply the power direct on them, the difference in the test was most serious, which, together with the fact that Martin's 61 cwt. dragged, while Smith's 48 cwt. held at Spithead, would make it appear that the orders spoken of had been given under a false impression. To come back to stockless anchors. They were very much indebted to Mr. Sivewright for his valuable paper on the subject, and thought he was right in saying that Messrs. Edward Withy & Co. were always foremost in all new efforts. In regard to his competitors in anchors, he thought they could quite well carry on their respective businesses without unfair opposition to each other. There was room enough for all, but no one had worked the stockless anchor more than he had done. He had kept steadily to it for eighteen years. He was sure drawing up the hawse pipe was the right thing. He thought they should discuss more the system than each other's patents. Lloyd's action should be discussed, in regard to their increase of weight by 25 per cent. in lieu of the stock. For seventeen years he had supplied his anchors *ex* stock weight complete, and never heard complaints of their being too light. He had put himself to some trouble to obtain the opinions of shipowners and officers who had used stockless anchors for many years, and, so far as he had received replies, in regard not only to his own but other stockless anchors as well, they thought any increase of weight in lieu of the stock was needless, and was likely to check an improvement, which ought not to be.

Mr. THOMAS RAY (by invitation) said there was one objection to all, or nearly all stockless reversible anchors, and his attention had been

directed to it by an old anchor maker. The objection was this, that it was highly improbable that the two arms would, even generally, have equal hold of the ground, and, in this event, the arm having least hold would most certainly "give." Now this of necessity would cause the other arm to have then only such hold that the edge of the arm would be in the direction of the strain, and thus the anchor would only be as a knife cutting the ground. This old anchor maker, who was one of the Hunter family long known on the North-East Coast as anchor smiths, and who had had much to do with Lieutenant Rogers and his experiments, went to see the launch of Messrs. Doxford's large ship, the "Trans Pacific." Now, in this case, although the anchors—Mr. Wasteneys Smith's patent—were placed very carefully, and, doubtless, supposed securely, in the ground, yet each anchor when the strain came turned or canted up on its edge, and thus lost all its holding power; in fact, these anchors at once did the very thing which the stock of the old-fashioned anchor was intended to hinder. The old-fashioned anchor, although generally considered one with only two arms, was in reality one with four, the work which it had to do, namely, in holding the ship, being divided among the four arms in the following proportions:—One arm for holding, two arms (the stock) for steadiment, and one arm in reserve. He therefore thought that the older form of anchor was, as regards certainty of holding power—truly the primary purpose of all anchors—superior to the hitherto known forms of stockless reversible anchors.

Mr. R. Thompson said, he had listened with great pleasure to Mr. Sivewright's paper on stockless anchors, and he wished simply to give his experience with them as compared with the ordinary anchor. As the result of their experience they certainly would not adopt the old anchor, but give the preference to the stockless anchors, where, as Mr. Smith put it, the price was made so that it did not come out of their pockets. They had fitted a Baxter anchor with a hawse pipe that enabled it to go in flush with the side plating. The enormous casting required would make it awkward if they had had to replace it, and was only adapted to one ship. They had also fitted Parkes' anchor and Smith's, and the only case of complaint of one of the stockless anchors in holding was on a muddy bottom, with a very strong current running. The ship had only one anchor down, and when the captain came home and told them about it, he (Mr. Thompson) said that if he had had thirty fathoms more cable out, it perhaps would have held. In another case, it was Baxter's anchor in the Mersey, and the whole of the ships at that time riding in the Mersey were dragging slightly. Our vessel had only one anchor out, but

the captain put out his second anchor, and the ship held all right, so that the actual experience with these anchors went to show that by allowing a little more cable when they were in extreme circumstances, with a soft bottom and strong stream, these anchors would hold for all practical purposes. There was the great fault of the old anchor holding too much. He had not known of a broken cable with the stockless anchor, whereas with the other broken cables were often heard of. The question whether it was better for the owner to have vessels liable to dragging a little, or broken cables and so being perfectly helpless would not be difficult to determine. He (Mr. Thompson) was present at Messrs. Doxford's launch, and it was quite true the anchors came out. They came out but took hold again, and the ship was stopped in the distance required. The weight and momentum had been calculated well, and the vessel was stopped in perfect safety. He thought, had these anchors held as it was supposed they ought to have held, probably the chains would have broken, and the ship gone further than she ought to have gone.

Mr. CHARLTON—Perhaps he was wrong in rising so often, but it had occurred to him that the "Trafalgar" had one of Martin's old anchors as well as one of the new kind. The old Martin pattern on being let go fouled the chain, and then the new one was let go and it brought the ship up very quickly indeed.

Mr. THOMPSON—What anchor was it that the Government had in the ship that broke adrift at Lisbon?

Mr. CHARLTON—The old Admiralty pattern anchor; but it was not the anchor that gave way, it was the cable that broke.

Mr. THOMPSON—It was just as he had said. Was it not true that the stockless anchor was the safest under all conditions in which it had to be tried?

Mr. CHARLTON—Yes; preferring to drag rather than break the chain.

Mr. H. WITHY thought the great question was whether the anchors had done their work, and not whether they were so much better than common anchors, and he held that the stockless anchors really did their work. The housing of the anchor was very handy. He placed very little value upon the Admiralty tests mentioned by Mr. Charlton. He was present at the launch of the "Victoria," and thought the best anchors there were some 26-ton armour plates which were used for checking.

Mr. J. HARTNESS said, he had listened to the remarks from the various gentlemen, both inventors and users of stockless anchors, and

he must apologise for not being in a position to offer any remarks with regard to trials; but this was his misfortune and not his fault. He thought it had been fairly agreed by authorities that the Admiralty trials had been always simply a farce, and were no more to be relied upon than a Will-o'-the-wisp. He was surprised to hear Mr. Charlton's statement as to the efficiency of Martin's anchor in comparison with its opponents, Messrs. Smith's, Tyzack's, and Baxter's patents. From the result of these trials, and in the absence of the respective weights of the anchor he should have been extremely surprised if Mr. Charlton's firm had not received the order. But in Mr. Hartness's opinion the apparent efficiency of the Martin anchor over its opponent was due to the diversity of weights. He (Mr. Hartness) had tested about 40,000 anchors during the last 23 years, and he did not think out of that 40,000 anchors he had tested more than a dozen of Martin's, and that if they had not been abandoned he could nevertheless tell them of a few hundred cwts. in London that could be bought very cheap. With regard to the remarks respecting holding power of anchors and the different conditions under which they were used, he was of the opinion of the last speaker, viz., the proof of the pudding was in the eating, and that stockless anchors had undoubtedly answered the purposes for which they were intended. He could not speak perhaps so decidedly as Mr. Smith and Mr. Tyzack, but he could say, so far as he had gone, and having tested both anchors, they had always sustained the test requirements of them as favourably as the best of the Admiralty anchors that had come under his notice. As regards the stockless anchors rolling when used for launching purposes, he submitted the conditions were altogether different, for neither the stockless anchor nor any other ship's anchor was intended for launching purposes. The conditions were so far apart that it might as well be said, by way of an illustration, fix a water-wheel in the stern of a vessel and expect the vessel to be propelled simply because it was a water-wheel. The strains were altogether different, and immeasurable, and he did not think because a stockless anchor had not held in launching it would not hold at sea; in point of fact he knew they did, and that even at the cost, which is gradually being reduced, stockless anchors had been entirely a success. In fact it did not require a philosopher to point out the great advantages of this type of anchor compared with the old one from every point of view, especially so in the case of large steamers; and he could support the statement that when stockless anchors were used there was far less risk of breaking the cables. During his experience he had found both cables and hawse pipes seriously

damaged and even the old type of anchor frequently lost on the old system of heaving the anchor, owing to the sudden strains brought upon them prior to the anchor breaking ground, or during the time of breaking ground, and taking hold abruptly. He (Mr. Hartness) thought that properly constructed stockless anchors had all the holding power necessary, and pointed out that to accomplish this they should have as much natural trip and therefore as little artificial trip as possible. With these requirements well considered, coupled with reasonable cost of manufacture, he had no hesitation in stating that the days of the old anchors were numbered.

Mr. J. W. SQUANCE said, he was not a maker of anchors, but he had had considerable experience in the working of them. He was never *shipmates* with a stockless anchor, but he had paid a good deal of attention to them since leaving the sea. He had been accustomed to the use of Martin's anchors in some of the ships belonging to the Peninsular and Oriental Company, and he could only say that they were the most awkward things to get on to a ship's bow that he ever yet handled, and he much preferred the old common or Rogers's anchor. As to the holding power of the Rogers's as compared with the stockless anchor; during the last year or two one of the ships with which he was connected was riding in a very heavy gale in Holyhead Bay, with two Rogers's anchors down. The stocks of both anchors broke, the anchors fell over and lost all holding power, and the ship began to drive. There was a very heavy sea running at the time, and the bay was full of shipping. It was found impossible (with the cables hanging to the bows) to steam the ship out to sea in the teeth of the gale, and to avoid doing serious damage to other ships she had to be put before the wind and run on shore; and but for the fact that she struck on the only bit of sandy beach in the whole bay she would have been a total loss. A few months later another ship (fitted with Mr. Smith's anchors) was riding out a heavy gale on the same coast with only one anchor down. In this case the anchor did not *come home* at all, but the cable broke, and the second anchor was let go and held the ship till the gale was over. But (as several gentlemen had said) the great point in favour of stockless anchors is the ease with which they are hove up and stowed. During his own experience at sea he had often gone out of a port (say like Malta, where almost as soon as the anchor is *weighed* the ship is in the open sea) on a dark, dirty night when the ship was diving into a heavy sea, and the only way to get the anchor on to the forecastle head was by sending a man over the bows slung in a bowline (who was sometimes hauled back half drowned) to hook on the cat block. This was both a difficult and dangerous undertaking, but with the stockless

anchors there was no necessity for it. On three different occasions (such as the above) he had had the bow of the ship pierced with the fluke of the anchor, and the fore compartment filled with water. This could not happen with the stockless anchors, as they were no sooner at the hawse than they were stowed and secured. Another point in favour of stockless anchors was the facility for letting go. When the old-fashioned anchor was let go *stock and fish*, that is, right from the forecastle gunwale, where it was hanging in some cases six feet above the hawse-pipe, the anchor had to fall nearly twelve feet before its weight came on the cable, and it frequently happened that the cable broke short off at the hawse. This, also, could not happen with stockless anchors as the cable always had the weight, and in letting them go there was no sudden jerk.

The VICE-PRESIDENT thought they should now bring the discussion of this evening to a close. It was a subject worthy of consideration in the interval, and some fresh light might be thrown upon several points to which he would just allude, and serve a very good and useful purpose. He wished to call attention to the fact, that for so important a subject they had not had that closeness of reasoning with regard to the more important points which, he thought, the subject deserved. There was a question whether the bow plates could be burst with loose flukes? The stockless anchor and Martin's anchor would be entirely in the same position—the flukes lying against the ship. With regard to the question of stock, there had been no reasoning brought to bear upon the stock itself. They had had a series of references to experiments where the stock existed, but the precise connection between the stock and the results had neither been debated nor demonstrated by data. The canting of Martin's anchor could be scarcely interfered with by the stock. It was a diaphragm, which, in a soft bottom, would at once enter and not resist canting at all. If that anchor had any less tripping tendency than any other anchor—either Smith's or Tyzack's—it could not be because of the stock in the form in which it appeared in Martin's anchor. This anchor had a considerable lifting action while the flukes were holding. If they *assumed* that with a short chain the stock was lifted off the surface, it could not possibly hinder the anchor from canting. He (Mr. Price) would undertake to demonstrate by ordinary reasoning that that anchor could not cant except on hard ground where the flukes would not hold, and would thus contribute to the canting of the anchor. In regard to what Mr. Ray said of the canting at the launch, the conditions were altogether different. The anchors were not probably put down on the line of the axis of the ship but at the side. He should never attempt to launch a big ship throwing a sudden strain upon a double fluked anchor

in that position, for the pull was obliquely to the path of the ship. In the launching of vessels they never had had a pull clean out of the ground. He thought the patentees of anchors of all kinds had contributed very largely to the improvement of the anchor itself. Whether it be the stock or stockless anchor there was an enormous advantage enjoyed by the mercantile marine, and he thought patentees were entitled to this acknowledgment from those engaged largely in shipbuilding. In regard to the stockless anchor, there had been no reference made to the circumstances in which a stockless anchor must prove of enormous advantage drawn up in the hawse-pipes. The other day he went to sea in a steamer that had earned some fame since. He went forward and his eye fell upon the anchors. He was struck with the lashings of the anchors, and concluded that they had not been unrove for a considerable period. He did not think that a condition for an emergency. The instantaneous use of these anchors was of vital importance to everybody on board that ship. He said nothing derogatory to the arrangement, but that they were incapable of that quick use which they perceived would be the case with Tyzack's anchor, the man only having to loose the break to drop the anchor, and immediately the ship was safely brought up. He would say this in regard to Mr. Sivewright's paper, that it was a valuable contribution to a subject too seldom discussed. So far as the position patentees occupied with shipbuilders it was rather an unfortunate one. Shipbuilders were really obliged to steer clear of patentees as much as possible, the real parties interested were the users. As a matter of fact, as soon as a shipbuilder advocated any patent, it was open to anyone to suppose he was an interested party, and his advice became of no value. The shipbuilder, as Mr. Thompson said, had to think of these things as it affected his pocket. This had been a very profitable discussion, and it would stand adjourned till next meeting.

Mr. THOMPSON wished to explain that the anchors used at the launch of Messrs. Doxford's ship, "Trans Pacific," had all angle iron stocks fitted to them.*

The discussion was then adjourned till the next meeting, to be held in Newcastle-upon-Tyne, on April 11th next.

* Mr. Ray has sent the following note:—"It was said by Mr. Thompson that Messrs. Doxford had fitted the 'Trans Pacific's' anchors with temporary stocks; and his remarks seemed to suggest that they acted as a hindrance rather than as a help to the anchors in holding. Such, however, could not possibly be the case if the stocks were placed right anglewise to the palms when in holding position; and as these anchors still acted uncertainly, it can only be said that they did so notwithstanding the help from the temporary stocks, which, however, in this case was probably not very much."—EDITOR.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887-88.

PROCEEDINGS.

NINTH GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, APRIL 11TH, 1888.

WILLIAM THEODORE DOXFORD, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Sunderland, on March 14th, which were approved by the Members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. T. Milton and W. G. Spence to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Jackson, Vincent, 19, Regent Street, Hartlepool.
Oglethorpe, William A., Messrs. Naval Construction and Armaments Co., Barrow-in-Furness.
Richardson, T., Jun., Hartlepool Engine Works, Hartlepool.
Robinson, William, 6, Choppington Street, Newcastle-on-Tyne (late Graduate).
Scott, H., 47, Mainsforth Terrace, Sunderland (late Graduate).
Smith, Charles Mayfield, 29, Mitchell Street, West Hartlepool.
Smith, Reginald Thomas, 77, Park Road, Newcastle-on-Tyne.
Tyzack, George, Dean Street, South Shields.
Watt, Robert B., 1, Mitchell Street, West Hartlepool.

ASSOCIATES.

Barklam, George, Tipton, Staffordshire.
Squance, J. W., 13, The Avenue, Sunderland.
Welford, Richard, Gosforth, Newcastle-on-Tyne.

GRADUATE.

Ingram, Herbert P., 30, Brougham Street, East Hartlepool.

Mr. J. C. STIRZAKER said, before giving notice of the resolution put down to his name in the circular convening the meeting, he should like to point out a little omission in the notice paper. The announcement should have read, "Mr. Stirzaker, *on behalf of the Council*, will give notice." It looked as if it were a personal matter—a private bill. He should like the meeting to understand that the resolution was a resolution of the Council. Another matter he should like to emphasize very strongly in order that this meeting might understand the reason for one of the chief clauses in the resolution was, that the subscription of the junior members would probably require to be very considerably raised, independently of any motion about reading-room or library. They would see the necessity of that when he said that in the second session of this Institution the cost per member to the Institution was £1 3s. 10d., towards which the junior members only paid 10s. 6d. and the graduates 5s. The third session the cost per member was £1 0s. 7d., towards which the junior members paid 10s. 6d. and the graduates 5s. The probable cost this session would be a little over £1: so they would see the absolute necessity of raising the subscription of the junior members, without any reference to reading-room or library. In the light of that fact he begged to give notice, that at the closing business meeting he would move on behalf of the Council:—

"That the members of this Institution, realising the many advantages to be derived by a reading-room and library, resolve that such shall be established in Newcastle-upon-Tyne at an annual cost not exceeding £150."

Further, "That inasmuch as the income of the Institution is not sufficient to meet the additional expenses which will be incurred, and that the junior members and graduates will probably be the most constant users of the reading-room, the necessary revenue shall be obtained by increasing the subscriptions of those members, namely, the 10s. 6d. subscription to be increased to £1 1s., and the 5s. subscription to 10s. 6d.;

whilst only the preliminary cost of furnishing, bookbinding, etc., which will amount to about £150, shall be defrayed by the other members and associates of the Institution, each of whom shall be asked for a donation of £1 1s., or as much more as he shall desire to contribute."

The PRESIDENT said, that before proceeding with the next business, he should just like to emphasize what Mr. Stirzaker had said, as according to the estimate, taking the full number of members, 700, they would have a deficiency of something like £50, so it was absolutely necessary that the subscriptions should be increased independently of the library. It was his duty to give notice that if the above resolution was agreed to, he would move that the following alterations should be made in the Constitution and Bye-laws :—

CONSTITUTION.

"V.—Members shall be Principals or Principal Managers engaged in Engineering or Shipbuilding ; Civil, Military, or Mining Engineering, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be *One Guinea* per annum."

"VII.—Graduates shall be persons under twenty-one years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscriptions shall be *Half-a-Guinea* per annum."

BYE-LAW 31.

Line 3, after "viz., one" insert Past-President or "Vice-President."

The PRESIDENT intimated that there retired from the Council this year, in accordance with the bye-laws, the present President, two Vice-Presidents, viz., Mr. Coote and Mr. John Price, and five Councilmen, viz., Messrs. F. C. Marshall, W. G. Spence, J. C. Stirzaker, Robert Thompson, and R. L. Weighton. On behalf of the Council he had great pleasure in nominating the following gentlemen from whom to fill up the vacancies in the Council for next year:—President—Mr. F. C. Marshall; Vice-Presidents (two vacancies)—Messrs. H. Macoll, W. G. Spence, Robert Thompson, and R. L. Weighton ; Councilmen (five vacancies)—Messrs. J. R. Fothergill, Thomas Millar, James Patter-

son, John Price, L. Rusden, A. Scholefield (Associate), and R. S. White; Hon. Treasurer—Mr. B. G. Nichol. In accordance with Bye-law 11 he (the President) invited other nominations.

There being none added the above list was adopted for the decision of the members.

The discussion on Mr. Sivewright's paper on "Stockless Anchors and Fittings" was then resumed; after which the adjourned discussion on Mr. Milton's paper on "Slide Valve Gears" was proceeded with. Mr. Alexander Taylor then read a paper on "Pontoon and Floating Docks."

ADJOURNED DISCUSSION ON STOCKLESS ANCHORS AND FITTINGS.

The PRESIDENT desired that the discussion should be confined to Stockless *versus* the Ordinary Anchors, not arguing in favour of any special anchor.

Mr. G. TYZACK said, he proposed in the first place to make some brief observations regarding stocked anchors generally, the object of stocks and their disadvantages; then to pass on to stockless anchors, their form, and the means designed for rendering their action efficient, independent of stocks; and lastly, a general criticism upon their construction. The object of the stock was to cause an anchor to lie in such a position that when the cable began to drag upon it the arm or arms penetrated the ground. When biting and holding, the shank and stock of an anchor should lie their entire length upon the bottom. When dredging was required, the cable was shortened and the stock end of the shank raised off the ground. The disadvantages of a stock were that it rendered an anchor very awkward to handle by reason of its being at right angles to the shank and arms; it was liable to foul the cable when a vessel had to swing round her anchor, and likewise sometimes fouled it when letting go, thus preventing the anchor holding; the stock was also liable to be broken on a rocky bottom. The ordinary stocked anchor was also very dangerous from its liability to foul other vessels, and in collisions frequently did more damage than the actual blow delivered by the colliding vessels. An instance occurred only in February this year in the collision between the S.S. "Edward Eccles" and the S.S. "Bradley," whereby both steamers had their bows and sides so badly torn open by the anchor that one had to have new plates, etc., put on, and the latter vessel went to the bottom, and, unless he was mistaken, remains there yet. The so-called stockless anchors were introduced to do away with these and other objections to stocked anchors, yet, practically speaking, even stockless anchors had a provision intended as an equivalent for a stock by having a hinged cross-piece or hinged arms at the crown end of the shank, the object being to cause the anchor to lie in a biting and holding

position. There were a number of stockless anchors at present before shipowners; perhaps a dozen patents could be named. A number of them were now illustrated both by models and diagrams. Of this number nearly all were more or less of one type, viz., the cross-piece with an arm at each extremity. Some of these had been in use for a considerable time, and very widely varying opinions were entertained and expressed by nautical men as to their holding qualities. The Admiralty had also given them a trial in vessels of various sizes, but, as in the case of the former Martin's anchor, after being some time in use they had doubts as to their reliability under severe strain, and a series of Government trials were instituted at Portsmouth in 1885 under the direction of the Admiralty, already alluded to by Mr. Charlton in his remarks. The upshot of these trials was that the two stockless anchors of this type tried were found to roll over when a heavy strain was put upon them, and consequently they had discontinued ordering them. In the short discussion which followed Mr. Sivewright's paper at the last meeting this rolling over feature was commented upon and not only admitted, but attempts were made to prove that it was an advantage, and instances were quoted to show that in some cases where they had been used in the launching of vessels, had the anchors not rolled out of the ground and lost their hold the vessels' cables would probably have broken and serious damage would have been caused. He could also instance a recent case per contra, where builders, being afraid of this rolling over feature of these anchors, had them backed up by ordinary anchors, and though the former rolled over the latter held, the cables did not break, and but for the precaution of backing up the stockless with ordinary anchors much damage would certainly have ensued. He begged to submit that in the case of a disabled vessel upon a lee shore in a gale of wind this rolling over feature would be fatal; and that anchors should be made and used which would hold on to the last extremity—all other considerations were of very secondary importance. Perhaps the very worst feature in the construction of most stockless anchors was that they had been designed with the one idea of lying close and snug up against a vessel's plating when drawn into the hawse pipes. This was no doubt a desideratum; but, unfortunately, in order to attain this end, holding power had been to a great extent sacrificed—the shanks had been cut down in size and length until they were about half the weight of that of an ordinary Rodgers's, Trotman's, or Admiralty anchor, and it was well known that weight and a reasonable length of shank were necessary to make an anchor lie steadily to its work of holding. To compensate for this loss of weight in the shanks of such

anchors, the hinged heads or cross-pieces carried all the extra weight, in most cases, in a solid mass of metal with very short arms which penetrated no distance into the ground, and instead of reliance being placed in the gripping and holding form of the anchor a mass of dead-weight material was expected to do this duty. He now proposed making some comparisons between the ordinary stocked and stockless anchors. The former had many disadvantages, but they admittedly possessed the one essential quality of a good anchor, namely, great holding power. This quality was very forcibly demonstrated at the Admiralty trials, especially in the testing of the ordinary Admiralty anchor, 49 cwt. including stock, suitable for a vessel (taking Lloyd's table as a guide) of 3,000 tons register, against a Martin's anchor, 60¾ cwts., suitable for a vessel of 5,500 tons register, nearly double the former. The trial was thus evidently a most favourable one for the Martin's, as the disparity in weight made the result a foregone conclusion; nevertheless, the Admiralty anchor showed tremendous fight and completely buried both its lower and upper arms and palms before it yielded, and then it only slowly dragged without losing its position, but had the stock been removed from the Martin's, notwithstanding its superior weight, the chances were it would have rolled out of the ground as others of a similar type had done. The great holding power of the Admiralty anchor alone accounted for its being such a favourite in the Navy and still so much in use in many of the largest vessels despite its clumsiness. The chief reason for its good holding was evidently attributable to the fact that the pull upon its arms was always in a direct line with the cable, whereas, in contradistinction to this, in the type of anchors with two hinged lateral arms the strain became unequally distributed owing to the improbability of each lateral arm finding exactly the same resistance in the nature of the ground when a heavy strain was put upon the anchor, hence one arm yielded sooner than the other, the anchor rolled itself over, and lost its hold. The construction of nearly all the patented anchors with hinged arms or cross-pieces bore a close resemblance to each other, though in details of fitting they might vary, except in the case of two or three of them, wherein the idea of obtaining a central steadying and holding arm on the principle of the Admiralty anchor had been aimed at. In order, however, to make this central arm thoroughly effective, it was necessary that it should be fixed on the same axis as the lateral arms and move with them, also that the angle of the central palms be identical with that of the lateral palms, otherwise if not on the same angle the action of one would operate against the other. An anchor constructed on the lines indicated practically

combined the holding qualities of both the single and double grip types of anchor and was more than equivalent to a stockless anchor backed up by a stocked anchor, for by receiving the strain simultaneously and equally upon three arms connected with one shank the action of one type was steadied and controlled by the action of the other, and the absence of a stock did not effect the steady holding of the anchor. Such an anchor had no tendency to roll over with a strain upon it. This was easily proved to be the case by trying the same anchor first with a central arm, then removing it and substituting in its place a central tripping stop block. With the former the anchor held steadily; with the latter it held and rolled over. For the purpose of illustrating his statement he had brought with him two models of the same anchor fitted in the two different manners named.

Mr. J. F. Hall, of Messrs. Wm. Jessop & Sons, Sheffield, being invited by the President to speak on the paper, said, as the inventor of one of the anchors depicted on the wall, he should like to point out a slight error that the writer of the paper (Mr. Sivewright) had made, but which was easily accounted for. He said it would be noticed in the designs of several other anchors, besides his (Mr. Hall's) own, that "the tripping power was at the centre of the head." That was true in the original model he brought out, but since then he had altered the design, as they would see it in the model before them. He had really put a stock on it, but in the right place, viz., at the bottom. He had done that in consequence of the action recently taken by Lloyd's Committee, when they made the new rule, claiming to have the weight of stockless anchors the same as those with a stock on. He (Mr. Hall) was not at the meeting when the paper was read, but understood from several members that a great deal was said on the subject of Martin's anchor. Well, there was no doubt that Martin's anchor as a stock anchor had been a successful one. He had conversed a short time ago with one of the admirals in the English Navy who had been accustomed to use the Martin's anchor. The admiral had told him that it was such a very important matter the anchoring of a large war-ship, that he himself had never felt satisfied until he had sent a diver down to see if the ship was properly anchored. If that was the estimation in which Martin's anchor was held in the Royal Navy, he thought there was some consolation for the upholders of stockless anchors. He did not know if the subject had been touched upon, but he should like to say a few words on the question of the report drawn up by the recent Anchor Committee of Lloyd's and the Board of Trade. With the introduction of stockless anchors, many had been made with steel castings;

in fact, most of them were made with steel castings. The action taken by the Committee in deciding upon the tests to be made upon these anchors was such that he thought no one using anchors could take any exception to; but he did think that the manufacturers of these stockless anchors and steel castings had a very great grievance, inasmuch as they were subject to these tests which were necessarily very expensive, whereas wrought iron anchors were passed through without any such tests whatever. He did not refer to the testing of the proof house—that was the same in all cases; but in addition to that, he might tell them, which, perhaps, some of them were not aware of—every part of a cast steel anchor had to have a piece taken from it, prepared and tested for tensile strain, and for bending. Also, each part of the anchor had to be lifted up 15 feet high, and dropped on to a cast iron plate, 5 inches thick. It was a very severe test, and although he, as a steel maker, did not object to it, at the same time he did think, and that most emphatically, that wrought iron anchors should be subjected to the same test. It was only fair that it should be so, particularly considering that wrought iron anchors were liable to have hidden and dangerous welds in them that even deceived the maker. Another matter in reference to stockless anchors, whereby the manufacturers had, to a certain extent, been boycotted, was that there were proving houses in the country that could not take stockless anchors. He (Mr. Hall) had sent an anchor first to one proving house, then another, and neither could take it into their machines. They were not adapted for stockless anchors; and if stockless anchors were going to increase in use, which he had no doubt they would, particularly after this very valuable paper of Mr. Sivewright's, it behoved all who had charge of proof houses to see that their machines could take in stockless anchors of any size. He did not think he could say anything more. He was sure, as an outsider, he felt very grateful to Mr. Sivewright for this valuable paper. It was a subject he had taken considerable interest in, and he thought the paper would do good, and be of very great benefit.

Mr. N. MacNicoll, of Messrs. MacNicoll & Co., of Glasgow (by invitation), said, his firm were the proprietors of the patent taken out in the names of Messrs. Scott & Riddel, who were mentioned, in the paper under discussion, as having first hit upon the idea of drawing the shank of a swivelling-fluked stockless anchor up into the hawse pipe. To a certain extent this was correct; but Mr. Scott, of the two named on the letters patent, was the real originator of the invention. It was not, however, anticipated that shipowners would be satisfied with merely drawing the

shank in, that being the way in which the idea had been worked out in the arrangement more particularly described in the paper, and he framed his specification to provide for bringing the anchor, flukes and all, inside of the line of the bow plating or planking. Where the shank only was drawn up, the flukes and their horns were left to protrude, in some cases, about two feet on each bow, and many shipowners, especially those with sea-going experience, thought this very objectionable, although much better than catting and fishing. It certainly, however, had one advantage in being cheaper to fit and in not being taxed with any royalty to the originator of the idea or those associated with him in bringing it into notice; and in these days of keen competition many were inclined to bear with the unsightliness of the projection even with the increased risk of damage in a collision, rather than be at the expense of the better mode; while many others did not know that for a little extra cost they could adopt the improved arrangement. The Bombay Steam Navigation Company had three new steamers fitted recently with Messrs. MacNicoll & Co.'s latest arrangement under Scott & Riddel's specification —the "Zuari," "Mandovi," and "Rajapuri," and in the latter an ordinary-sized hawse pipe was cast with pockets on each side, and with a flat horizontal base or flange connected to the bow plating by simple plates and angles, costing very little extra. This was reported on by the captain, who took charge on the voyage to Bombay, as having worked without a hitch of any sort, as was also the case with the others. The owners have since this arranged for its introduction in two other steamers lately contracted for. With reference to the efficiency of stockless anchors, the chief officer of another steamer, while giving a report favourable without any exception as to the working of her self-housing arrangement during the first twelve months of her running on the West Coast of Scotland, stated that he had found the anchors, which were of Mr. Wasteneys Smith's patent, capital holding anchors, and that he had ridden through gales of wind without ever requiring to put down more than one of them. He (Mr. MacNicoll) considered this valuable testimony on the question of "stockless" *versus* "stocked" anchors.

Captain ROOKE (by invitation) wished to state that he was connected with a large steam shipping firm in West Hartlepool, and during the last four years stockless anchors had been in use in their new vessels; indeed they were the first that adopted stockless anchors in vessels sailing out of the port of Hartlepool. This type of anchor had given such satisfaction that they were fitting them in three of their new ships now building. They were not only very handy for working, but he believed they laid

hold readily, and that their holding power was better than anchors fitted with stocks. Some six or seven months ago they had had a very practical illustration of the holding power of Mr. Wasteneys Smith's stockless anchors. They were bringing one of their new vessels in ballast round to the Tyne during stormy weather, and in coming up the river, the vessel being very light forward, a heavy squall of wind took her on her starboard bow; the ship ran off against the port helm and made straight for a tier of steamers There was no time to reverse the engines, and the only chance to prevent a very serious collision was by rapidly dropping the anchor. They happened to have one of Smith's patent stockless anchors hanging in the hawse pipe, and it was let go immediately (the engines at the same time being reversed full speed astern). The instant that this anchor touched the bottom it took hold, drawing the ship's head to starboard; and to show the splendid holding power of this anchor the vessel ran away with fully 90 fathoms of chain, as the anchor had such a firm hold that the brakes on the windlass were not powerful enough to start it or stop the cable running out; in fact, in the whole course of his sea experience he had never seen an anchor take hold so quickly. As a rule, when common stocked anchors were dropped in shallow water, they did not readily take hold, and the chain had to be helped over the windlass to allow the anchor to fall into a holding position; but, in the case mentioned above, the stockless anchor seemed to seize hold in a moment, and they were so pleased with the whole arrangement, and had had such good reports from their captains, that they were resolved to go in for nothing else in future but stockless anchors. They certainly had no complaints about breaking plates at the bows of vessels since they adopted the stockless anchors. This was quite a common occurrence with the old form of anchor; and indeed, within his own knowledge, they had had some ten or twelve cases of the bows being stove in. In entering foreign ports they hardly had the pilots on board before they ordered the anchor over the bows; if there was a heavy sea running at the time it was quite easy for damage to be done by the anchor rolling about and the flukes cracking the plates, or the plates being stove in. Having some twenty steamers, they were largely their own underwriters, and he considered it was more to their interest to adopt the stockless form of anchor.

Captain M'NABB said he laboured under a disadvantage in not having heard the paper read. It seemed to him, however, that the discussion that evening had not been whether the stockless or stock anchor was the best. The gentleman who first spoke (Mr. Tyzack) seemed to refer principally to his particular anchor. He (Mr. M'Nabb) did not know,

except from what Mr. Tyzack said, that the one anchor had been proved better than the other by the Admiralty test, and Mr. Tyzack had stated that the Admiralty tests proved the old stock anchor to be the best of all. His own experience had been very considerable, and he might say that he had not in his experience had anything to do with stockless anchors; but were it not for certain disadvantages he should never change from stock to stockless anchors so far as holding power was concerned. He was quite content with them; in fact, in ordinarily good holding ground, he had broken his windlass before getting the anchor up, and this was a Rodgers's. He would not himself, were it not for certain advantages connected with the stockless anchor, change from Rodgers's or other stock anchor to the stockless anchor. In his view there had been no evidence given that night that the stockless anchor beats the stock anchor in holding. He took it that it had been the other way. Therefore, he did not see why they should change so absolutely from the one class of anchor to the other without very good reason. Some had been given, but to his mind they were not quite sufficient. He was inclined to doubt the statement of the gentleman who had last spoken (Capt. Rooke) that the stockless anchor held better. He (Mr. M'Nabb) took the contrary view, viz., that the stock anchor would hold better than the stockless one—the stockless anchor being liable to roll. His contention was that, given a sufficient strain, the stockless anchor would roll, whereas a stock anchor, if it did roll, the stock would turn it over again into its proper position. The matter Mr. Tyzack mentioned in regard to the stockless anchor was an important one and sufficient to condemn it. There was no chance of fouling in letting go; but it was to be borne in mind they had not now to deal, as in years gone by, with sailing vessels they could not swing in a tide-way and to trust to a sail to keep her clear of her anchor, for now they had steam power to help them. The gentleman who spoke last (Capt. Rooke) seemed desirous to advertise Mr. Wasteneys Smith's anchor. It was unnecessary, however, for his anchors were sufficiently well known. Coming into the Tyne, Capt. Rooke told them, they should have done some damage had it not been that the anchor was so easily let go. Any sailor coming into a place like the Tyne would have his anchor ready to let go, and he did not think Smith's, Martin's, or any other anchor, provided it had arms or shank, would fail to hold if they paid out 90 fathoms of chain. The main reasons in favour of stockless anchors seemed to him to be that they were easily stowed, especially with the large hawse pipes, and easily got rid of. The question to him seemed to be, not the superiority of one type of anchor compared with another, but

simply that the stockless anchor, with the large stowing hawse pipe, had certain advantages over the stock anchor, which he would not for a moment deny, but more than that he would not concede.

Mr. G. W. SIVEWRIGHT, in reply to the discussion, said he thought the whole point at issue was—had the stockless anchors now in use done their work efficiently? He maintained that they had, and considered, in combination with the housing arrangement, that they were a decided success. In some twenty vessels built under his supervision, and fitted with stockless anchors housing into pipes, he had received from the officers in command the most gratifying reports as to their holding powers and general handiness; and he was so pleased with the whole arrangement that in future all vessels built under his charge would be fitted with stockless anchors in preference to any other design. The fitting of stockless anchors housing into pipes was more expensive to shipbuilders than the old arrangement of anchors and fittings; this being the case, he thought the members of this Institution would agree with him when he suggested that it must be something more than mere sentiment that would influence shipbuilders to incur the extra outlay.

Mr. Charlton, in his remarks, would lead the members to suppose that the Admiralty trials proved the superiority of the Martin stocked anchor over all others, but when they considered that the Martin anchor used at these trials was over 60 cwt., and the others in competition varied from 35 to 48 cwt., they might reasonably suppose that if these tests were in favour of the Martin anchor, that the extra weight had more to do with the results than any superiority of design.

Several members had remarked upon the behaviour of stockless anchors when used for checking purposes during launching operations. He quite agreed with Mr. Price that the launching test was not a fair test of the holding capabilities of any anchor, as the strains brought to bear upon them when used for this purpose were entirely different to the strains when the anchor was in use at sea. He had used stockless anchors for checking purposes at the launch of twenty vessels. At the first two or three launches he found that the double fluked anchors appeared to take all the strain to start with, and in some cases they left the ground, but, after "skidding" for five or six yards, they took hold again. In further experments he came to the conclusion that this "skidding" was due to the hard nature of the ground, and this really proved to be the case, for when the earth was loosened somewhat in the way of travel of the anchor flukes, so that they could dredge freely, the behaviour of these anchors was all that could be desired. It was not a new occurrence

anchors leaving the ground when used for checking purposes, and it had happened many times before with stocked anchors, indeed, the custom of placing a second or back anchor was to prevent or minimise this.

The shipping community of this country were under a deep obligation to the patentees of stockless anchors for the persistent way they had always kept their anchors to the front; and it must be gratifying to makers at last to find that their exertions have not been in vain, and that this class of anchor is now coming into general use.

He considered that the stockless anchor housing into pipes was one of the most useful inventions that had been introduced to the shipping public for a number of years; and he was quite convinced of this that, if stockless anchor makers would keep their prices low, it would only be a question of a very short time of the stocked anchor being driven entirely out of use in the mercantile marine.

The PRESIDENT moved a vote of thanks to Mr. Sivewright for his paper. At first it would appear as if a paper upon so comparatively small a portion of the subject with which naval architects had to deal would not cause much discussion, but they had had an altogether most interesting and thoroughly able discussion upon the question of stockless anchors, and especially by captains who had had experience with them. Unfortunately these practical men differed in opinion as to whether the stockless or stock anchors were most reliable. He had great pleasure in moving the vote of thanks to Mr. Sivewright for his paper.

The motion was agreed to.

ADJOURNED DISCUSSION ON SLIDE VALVE GEARS.

The adjourned discussion on Mr. J. T. Milton's paper on "Slide Valve Gears" was resumed.

Mr. D. B. MORISON said, that had he been able to be present at the last meeting, it was his intention to refer to the paragraph in Mr. Milton's paper in which he said the swinging link valve gear, described by the late Mr. Wyllie before the I.M.E., was identical with one form of Mr. Marshall's. Mr. Marshall opened the discussion by explaining that the gears to which his name was often attached were not his at all, although, at the time of patenting them, he thought he was the first inventor. Mr. Milton was evidently not aware of the extent of Hackworth's inventions, or he would have given him a little more credit than he had done; and Mr. Marshall also, in his (Mr. Morison's) opinion, was not exactly right in saying that what he termed his "unfortunate" gear, should properly be called Bremme's gear. If Mr. Milton had examined the published reports and illustrations of Hackworth's gears, he would have found that, as far back as 1859, Mr. Hackworth was thoroughly conversant with the gear he described as Marshall's. In fact, Figs. 31 and 33, Plate XXXIX., are reproductions of illustrations published in that year. In 1876, Hackworth described and illustrated a gear, as shown in Fig. 32, Plate XXXIX., which Mr. Milton had referred to as the second form of Hackworth's gear. It would be seen that the only distinctive and novel feature in this gear was the altered position of the fulcrum, from beyond the valve spindle attachment to a point between that and the eccentric, consequently all the arrangements of gears invented by Mr. Hackworth in 1859 might be modified in this manner. For instance, Fig. 34, Plate XXXIX., was an evident modification of Fig. 33, and Figs. 31, 32, 33, and 34 represented valve gears as invented by Hackworth prior to 1876. The late Mr. Wyllie fully appreciated the value and extent of Mr. Hackworth's inventions, and only considered the gears described by him in his paper as modifications, containing some elements of novelty as regards arrangement and proportion. The gears 31 and 33 are of course in a much better condition as

regarded stresses than 32 and 34, but the amounts in each case could be very nearly approximated; and as the various parts of a valve gear were designed for the loads they had to bear, he could not see why the fact of a valve seizing, as mentioned by Mr. Marshall, would cause any more damage in the one case than in the other, although, of course, he granted that the form 31 and 33 would allow of much lighter gear and smaller surfaces. In 1879, a Mr. Bremme illustrated a gear, Fig. 35, Plate XXXIX., in connection with a steering engine, and had since published an advertisement pamphlet of several other forms, some of which might be found in the new edition of Seaton's manual. Since, however, he seemed to insist that Hackworth had no right whatever to modifications, it was strange he did not adhere strictly to his own illustration, Fig. 35, where the reversing lever was placed on the opposite side from the valve spindle.

Mr. MILTON, in reply to the debate, said there had been so little discussion on the paper that he did not see any point raised to which one could make reply, except Mr. Morison's remarks. He had apparently misunderstood the subject of the paper, which was not to go into any question of the priority of patents. He (Mr. Milton) was not a patent agent nor a patent expert. In mentioning Marshall's gear and Kirk's gear, etc., he had given the names under which the gears were generally known and referred to. He had seen many engines, but he must say he never saw an engine fitted with gear known as Bremme's gear, and only one engine fitted with gear called Hackworth's gear, made by Mr. Morison's firm many years ago. When Mr. Wyllie described these gears he did not call them "Hackworth's," but "swinging link gear." One remark Mr. Morison made about valve gear was with reference to the strain upon them. Any disadvantage in regard to strength could generally be remedied by putting in sufficient weight, and if it were a case of wear and tear, by putting in sufficient surface. But some kinds of surfaces were found not to wear as well as others. Sliding block gears would generally be superseded by swinging link gears, for sliding surfaces could not be kept true unless they had an excessive amount of surface. In all kinds of machinery with which he was acquainted, if it were possible to supersede sliding surfaces by rotating surfaces it was done. The only part in a marine engine where the sliding block was retained was the piston rod cross head, where guides had superseded the old-fashioned style of parallel motion. If they considered the surface necessary in a piston rod cross head, compared with the load upon it, and contrasted them with the surface and load upon the crank pin, they would see the great advantage in using the circular motion

To illustrate Mr D.B. Morison's remarks on Mr Miltons paper.

HACKWORTH'S VALVE GEAR.

FIG. 31.
1859.

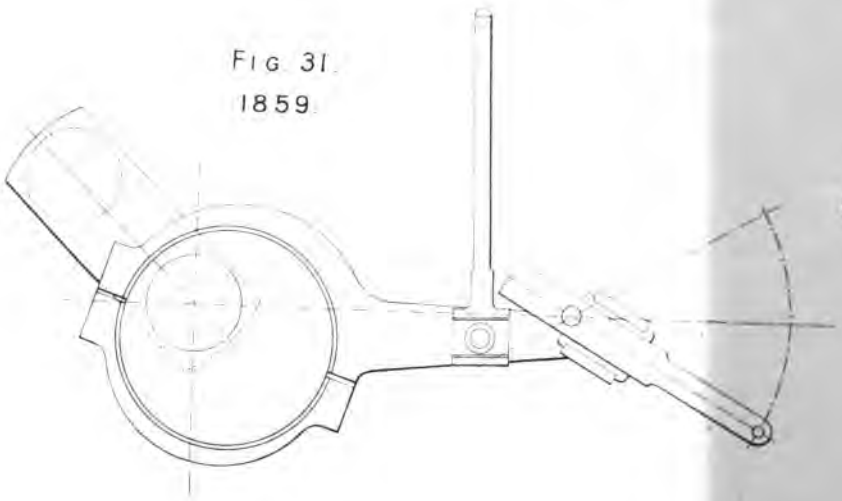


FIG. 33.
1876.

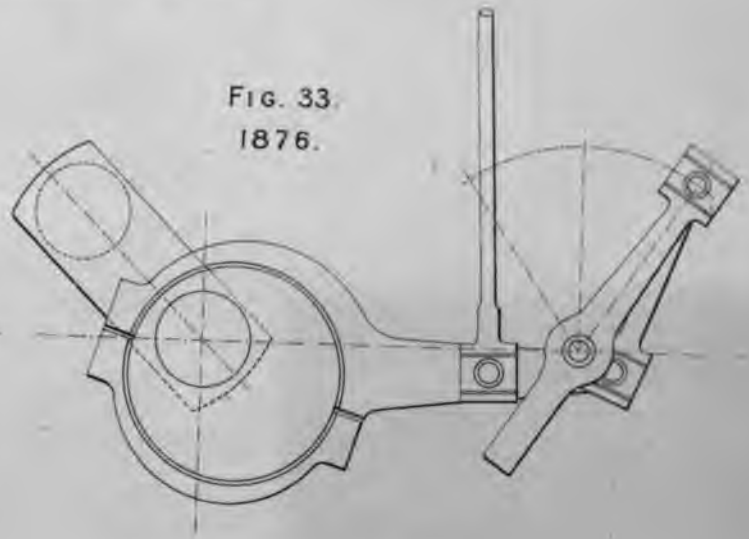
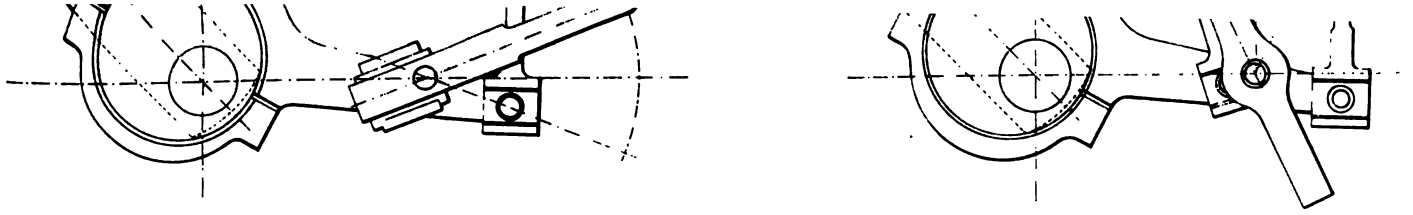


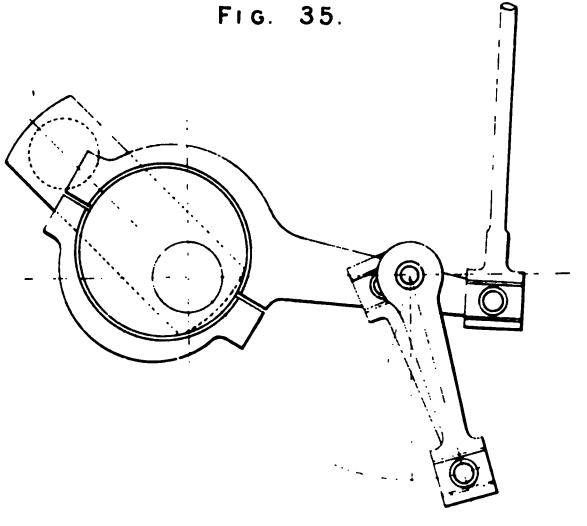
FIG. 32.

FIG. 34.



HACKWORTH'S VALVE GEAR
AS APPLIED TO BREMME'S STEERING ENGINE.

FIG. 35.



instead of the sliding motion. Mr. Weir mentioned a gear as having been applied in certain cases; but practically it was the same as one form of Mr. Bryce Douglas's gear. The valve took its motion from a swinging lever in the same way, one end being worked direct from the piston rod, the other from the eccentric at right angles to it. The main object of the paper, which appears not to have been noticed in the discussion, is to show the small amount of difference in the motion produced by the different gears, so that the advantage or disadvantage of any special gear will depend mainly upon its simplicity, freedom from excessive wear, and ease and certainty of its accurate adjustment.

The PRESIDENT said he was sorry that Mr. Milton's paper had not caused longer discussions, but he was sure they would all accord Mr. Milton a hearty vote of thanks for the very able and interesting paper he had read before them.

The vote of thanks was agreed to.

PONTOON AND FLOATING DOCKS.

By ALEXANDER TAYLOR, M.I.N.A., Vice-President.

[Read before the Institution, Wednesday, April 11th, 1888.]

In this paper any floating structure having open ends, and sides of equal and uniform section throughout, by which ships are lifted out of the water, will be called a "Floating Dock," but structures having sides varying in height and of less displacement than the bottom tanks will be called "Pontoon Docks." The sides are supposed to commence at and rise above the deck. The deck is the platform on which the keel blocks rest.

In designing an open ended floating or pontoon dock to lift a ship of given maximum size and weight it is necessary—

1st.—For the under deck displacement of the dock to be greater than the combined weight of ship and dock.

2nd.—The dock should be sufficiently strong not only to support the intended maximum ship, but so strong that it will not be injured if the ship has been built or damaged in such a way that a great part of the ship's weight rests either amidships or at the ends.

3rd.—The sides should be made as low and narrow as efficiency will permit, so that a wide working platform may be secured and light and air have access to the ship, and that the topweight and displacement be a minimum.

4th.—The water should only have a limited cross range in the tanks.

5th.—If the dock is emptied by pumps, the pumps should be close to the bottom of the dock, so that the water may as far as possible run into the pumps without having to be drawn in.

The pontoon built under the writer's letters patent for the Tyne Pontoons and Dry Docks Company, Limited, Wallsend, fairly fulfils the above conditions.

Fig. 1, Plate XL., is a longitudinal view of this pontoon.

Fig. 2, Plate XL., is a plan.

Fig. 3, Plate XLI., shows two half cross sections, showing the keel blocks supported on three longitudinal girders, G, F, and G^1. These girders are stiffened by intercostal plates A on every third frame. Stanchions are fitted to the intermediate frames. The frames throughout are 31 inches from centre to centre. The transverse bracket plates in tank C are on every third frame, but in tanks D and E are only on every sixth frame.

The frames between the gusset plates are fitted with stanchions. The longitudinal water-tight girders are shown by F, G, H, I, K. Three transverse bulkheads divide the pontoon tanks into four longitudinal parts, as shown on the plan, Fig. 2, forming altogether twenty-eight separate tanks. The plan also shows that the tanks terminate some distance within the ends and sides of the pontoon (although means are provided by which part of the space between the tanks and pontoon sides may also be used as tanks if necessary). This arrangement permits of an all round internal examination and free communication between the two engine rooms when the pontoon is sunk. The outside shell-plates, up to and a little above the tank top, are $\frac{7}{16}$ inch thick. They and the tank top-plates are double riveted in seams and butts throughout.

Two centrifugal pumps, engines, and boilers are placed in the forward end. The pumps draw from the main cross drain (M, Fig. 2) which forms part of the structure, and is in communication with the various tanks adjoining. The pumps appear to be well placed, for they have pumped freely. There is a sluice valve (S) in the cross drain in the longitudinal centre line, so that usually the port pump only pumps from the port tanks, and the starboard pump from the starboard tanks.

Before sinking the dock the distributing valves shown on Fig. 2 are opened, and remain open until the dock is raised again. In fact, it would perhaps be better not to have these distributing valves, but to draw direct from the end of each tank, and thus each longitudinal set of tanks would be entirely independent of its neighbours. The water coming in or going out is entirely controlled by the admission or exclusion of air from the various tanks; that is, if in lifting the dock it was considered necessary to keep the water in any particular tank, the air pipe for that tank would be kept shut, and this gives the necessary control over the water. The pumps are run full speed during the lifting of a ship, and

the man superintending the raising is on the dock or ship and controls the air pipes, as above described. There are two donkey pumps and a range of piping, by which the tanks can be more completely drained, the dock washed, or ships supplied with water to test tanks, fill boilers, etc.

The pontoon was successfully launched, broadside on, in a nearly finished condition, into a space little wider than twice its own breadth. The launching ways were fitted so as to form an arc of a circle. A ship was docked and lifted within a week after the launch. It has been in constant use for three years, and has lifted 170 steamers in that time. The largest ship lifted measured 300 feet long, 37·3 feet beam, and 27·3 feet depth of hold to upper deck; the ship overhung the pontoon 25 feet at one end and 15 feet at the other. A ship can be lifted and sighted in about an hour and a half. To show its adaptability, and the ease with which it can be worked, it may be stated that a steamer was undocked and the pontoon lifted, and all the keel blocks moved and set in two rows to suit a centre ladder steam hopper dredger, and again sunk and the dredger lifted, all in one tide. The pontoon is lighted by gas throughout.

Some such reasoning as the following led to the sides being made in form as shown by Fig 1, Plate XL. A ship to be moved into a dry dock or on to a slip must have sufficient stability in herself, or ballast must be added to give the necessary stability before she can be moved ; therefore, in this condition she requires no external aid as far as stability is concerned. A pontoon when sunk, ready to receive a ship, must in virtue of its construction have the combined centre of gravity of the structure, and contained water some distance below its centre of buoyancy, and consequently it must remain upright, even if totally submerged. Now, as it has been shown that the ship must be stable, and the pontoon when ready to receive it has also considerable stability, it is evident the pontoon requires no sides above the water to give it stability at the time when it and the ship are first combined ; but while the water is being pumped out of the pontoon, the combined centre of gravity of the ship, pontoon, and its contained water, will rise, and the combined centre of buoyancy will fall, and therefore the dock must have sides to give stability as it rises, until ultimately the sides are made the full length, and the maximum stability is secured with a minimum of topweight and displacement. The sides being low allow light and air free access to the ship, and the ship's bottom is thus easily seen and rapidly dried.

Fig. 4, Plate XLII., is a cross section of the Rotterdam Harbour

shown by Fig. 11 is, that at a pontoon draft of 23 feet, there is 4½ feet metacentric height, with the combined centre of gravity 18 inches above the combined centre of buoyancy. And at a draft of 17¼ feet we have the least metacentric height, namely, 3½ feet when the combined centre of gravity is 6 feet above the combined centre of buoyancy. At 11 feet draft, when only the keel of the ship is in the water we have 9 feet metacentric height with the combined centre of gravity nearly 12 feet above the combined centre of buoyancy. And at 7 feet draft we have 33 feet metacentric height when the combined centre of gravity is 14½ feet above the combined centre of buoyancy.

The diagram, Fig. 12, Plate XLVI., shows the combined righting moment for the said ship and pontoon at 5 degs. list during the whole process of lifting the vessel from the time the ship touches the blocks to the time the dock is pumped dry. Where the curve of moments runs into the vertical ordinate at N, representing 7 feet draft, the righting moment is calculated for the water being over one half the pontoon deck, while the moment M on the same ordinate is calculated for the deck entirely free from water, in which position the dock invariably is when supporting a ship out of water. Of course it must be clearly understood that these diagrams, etc., give the model dock's stability under the most unfavourable conditions possible to conceive.

The PRESIDENT, at the conclusion of the paper, said it was intended to adjourn the discussion till the next meeting on the 9th May.

Naval Architects, in which he describes the Carthagena floating dock, and gave its righting moment at 10 degs. list when the deck is out of the water, and, at the same time, supporting a Spanish war vessel. This, of course, is a most stable condition for the dock when supporting the steamer. As far as the writer can learn from the paper, he does not take into account the effect of the contained water travelling over as the dock lists.

The diagram he gives is purely one point in the metacentric diagram This seems to be the usual way of showing a floating dock's stability, but it is, in my opinion, extremely misleading. The metacentric curve for docks is only useful as a means of comparison when the docks are of similar design and uniformly proportioned.

The writer will endeavour to explain this fully from calculations made for a pontoon dock which has not yet been built, so that no one can object to their publication, and it will be called the model pontoon.

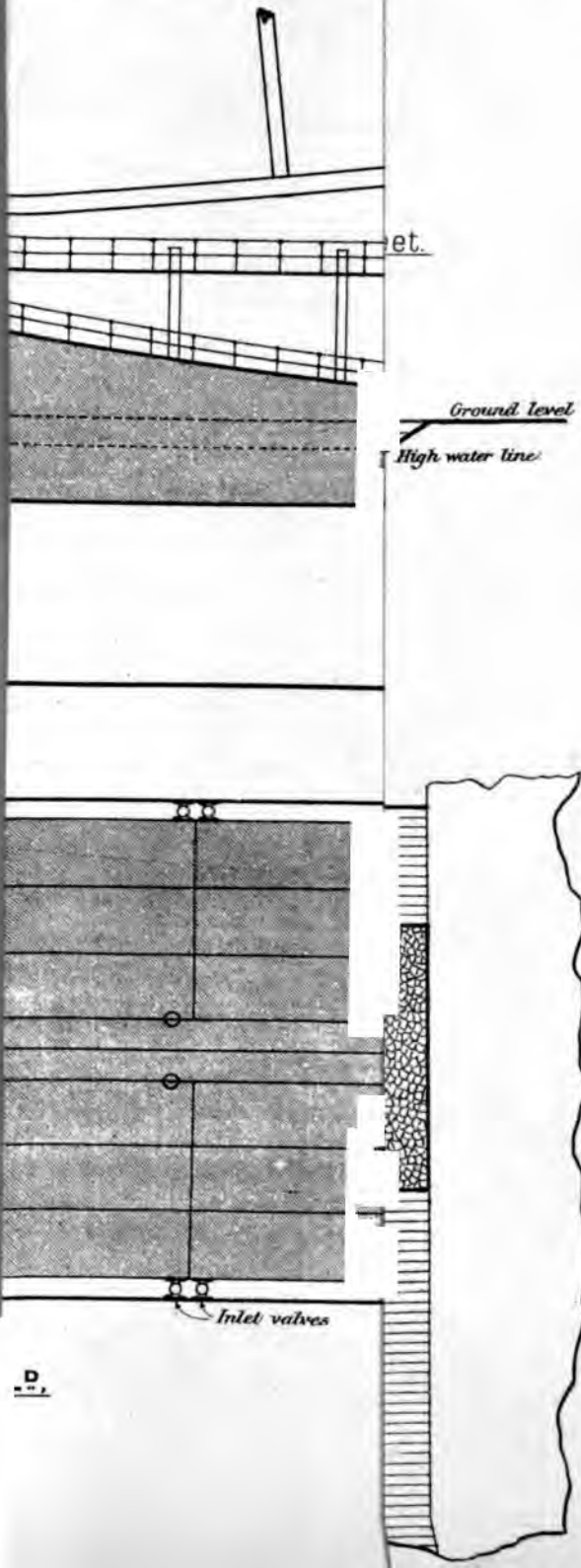
The curve D on the diagram, Fig. 11, Plate XLVII., represents the pontoon's displacement, M its metacentric curve, and B its centres of buoyancy curve. Fig. 11 also shows the displacement curve *d*, centre of buoyancy curve *b*, and metacentric curve *m*, of a deep, narrow, tender-proportioned steamer, which is supposed to be the heaviest and most awkward ship this particular dock is to lift.

The same figure also shows the before-mentioned curves combined in M^2, B^2, and also the combined centre of gravity curve G^2, as if the vessel and pontoon were one structure.

In making such calculations, it is necessary to be perfectly sure that, if there is an error, it shall be on the safe side; and, having this in view, the steamer's centre of gravity is supposed to coincide with its light draft metacentre G on Fig. 11, and we may take it that the steamer could not be moved into the dock if the centre of gravity had been higher. The centre of gravity of the pontoon is supposed to coincide with its centre of total displacement. This is also well on the safe side (Mr. G. B. Rennie places the centre of gravity of the Carthagena dock one-fourth lower). The centre of gravity of the water in the tanks is supposed to remain constantly at half the height of the bottom or under deck tanks. It is possible, under extraordinary circumstances, that the centre of gravity of the water may remain so high, but it is not possible for it to be higher.

Along with this explanation, it is necessary to say the calculations have been carefully made on the actual form of a ship and the model pontoon, having tanks arranged as shown on Fig. 10. You will notice the result

Construction of Pontoon



To illustrate Mr. A. Taylors paper on "The Construction of Pontoon Dry Docks."

TYNE PONTOONS & DRY DOCKS CO., LD.,

WALLSEND-ON-TYNE.

LENGTH, 260 FT.

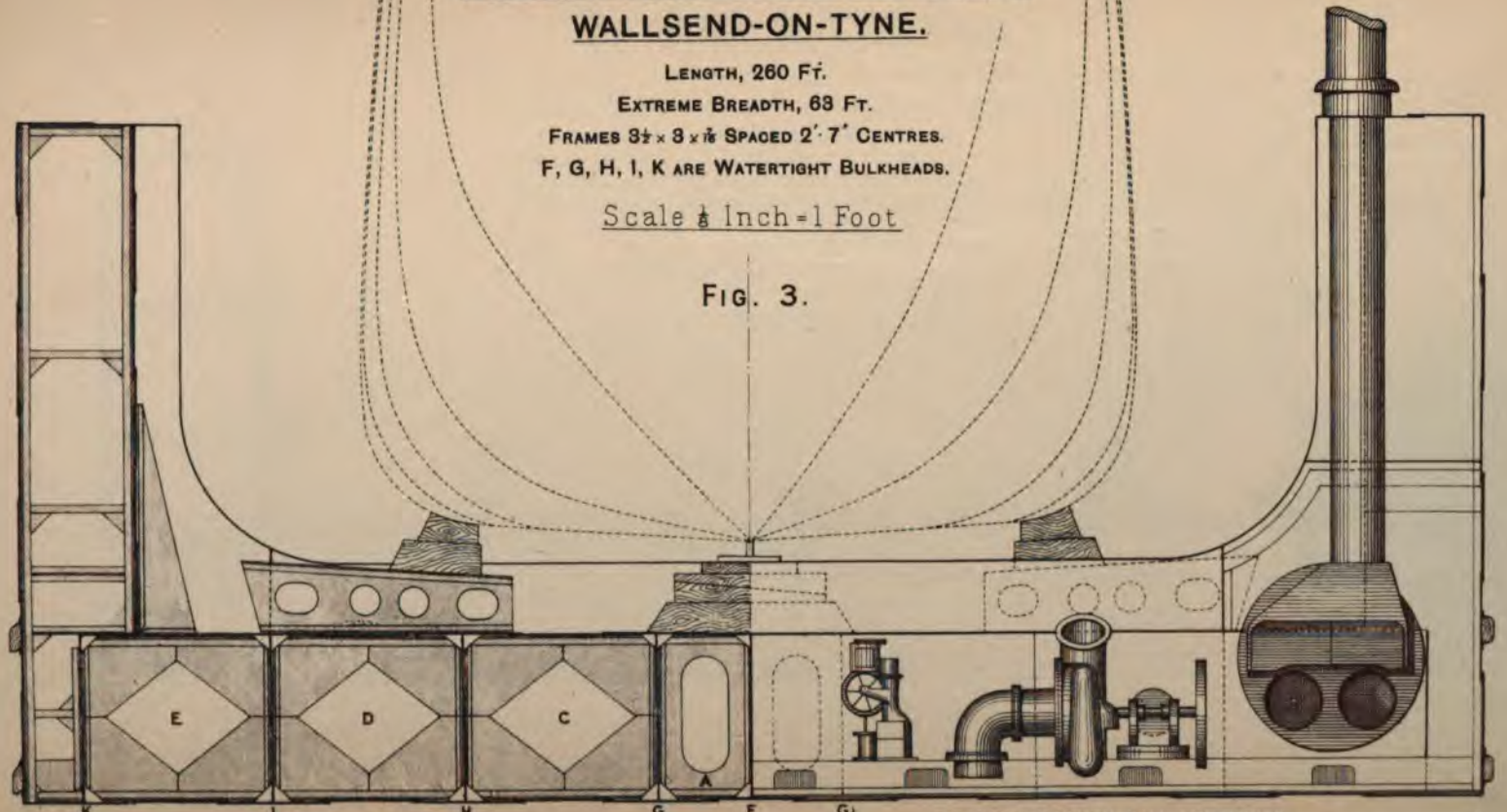
EXTREME BREADTH, 63 FT.

FRAMES 3½ × 3 × ⅜ SPACED 2'·7" CENTRES.

F, G, H, I, K ARE WATERTIGHT BULKHEADS.

Scale ⅛ Inch = 1 Foot

FIG. 3.



MIDSHIP SECTION — SECTION THROUGH SILL AND TOWER

Proceedings N.E.C.I. of E. 3 1887-88

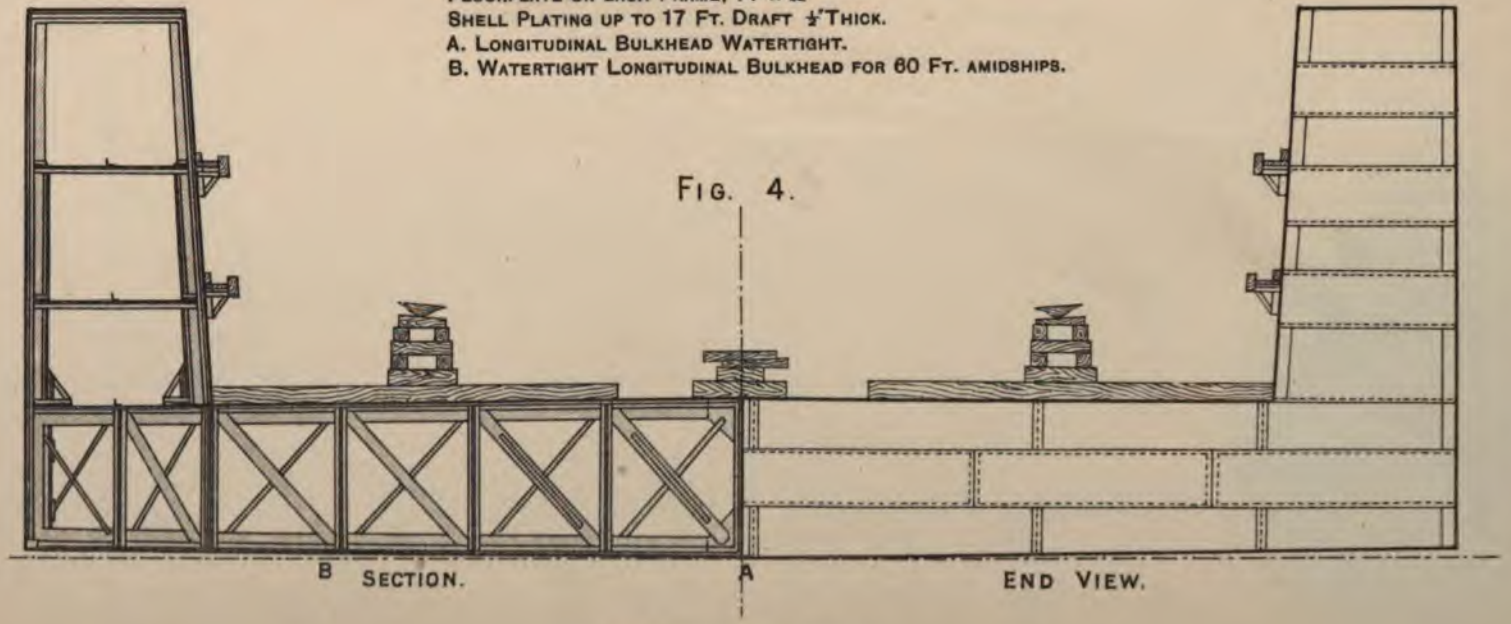
Andrew Reid, Ltd., Newcastle

ROTTERDAM FLOATING DOCKS.

LENGTHS, 297 FEET AND 158 FEET. EXTREME BREADTH, 90 FEET.

FRAMES DOUBLE ANGLES 4" × 4" × 13/32" SPACED 3'-3½" CENTRES.
FLOORPLATE ON EACH FRAME, 14" × 13/32"
SHELL PLATING UP TO 17 FT. DRAFT ½" THICK.
A. LONGITUDINAL BULKHEAD WATERTIGHT.
B. WATERTIGHT LONGITUDINAL BULKHEAD FOR 60 FT. AMIDSHIPS.

FIG. 4.



Scale ½ Inch = 1 Foot

To illustrate Mr. A. Taylors paper on "The Construction of Pontoon Dry Docks."

CROSS SECTION OF SOERABAYA FLOATING DOCK.

LENGTH, 197 FEET. EXTREME BREADTH, 72 FEET.

FRAMES 4" x 3½" x ⅜" SPACED 2 FEET APART.
FLOORPLATE ON EACH FRAME 8" x ½" ALL SHELL PLATING UNDER 2 FT. DRAFT ½" THICK.
A. AND B. ARE WATERTIGHT BULKHEADS.
C. IS A LATTICE WORK GIRDER.
D. AND E. DITTO OF LIGHTER CONSTRUCTION

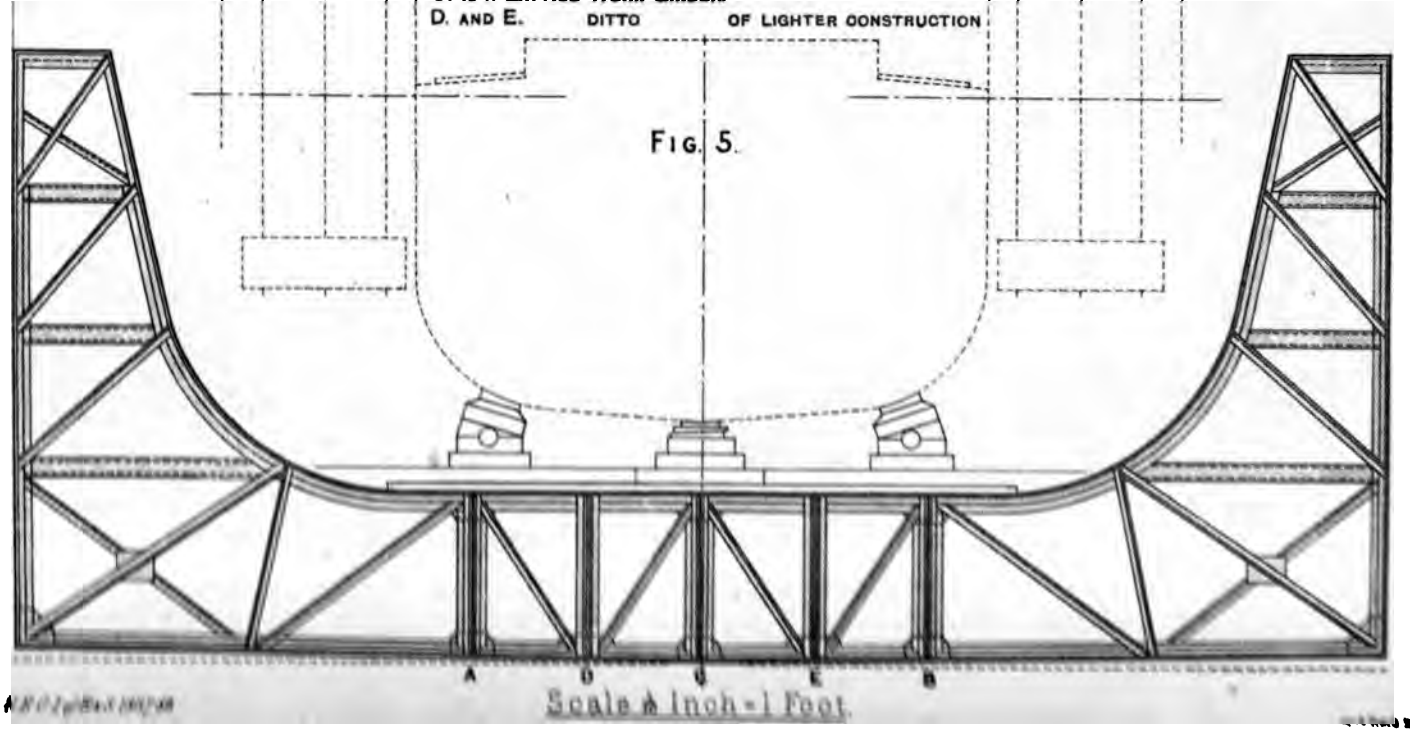


FIG. 5.

Scale ⅛ Inch = 1 Foot.

To illustrate Mr. A. Taylors paper on "The Construction of Pontoon Dry Docks."

CROSS SECTIONS OF SELF DOCKING PONTOON DRY DOCK

Fig. 6.

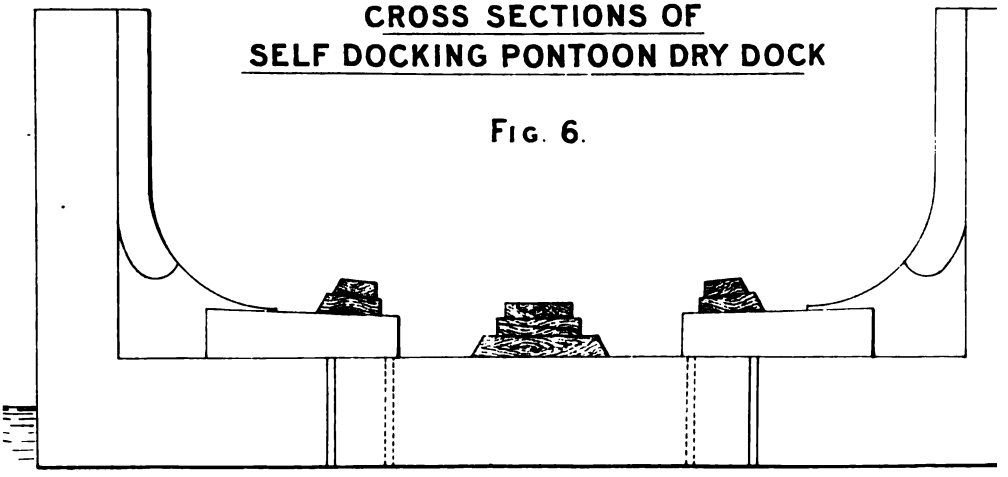


Fig. 6. a.

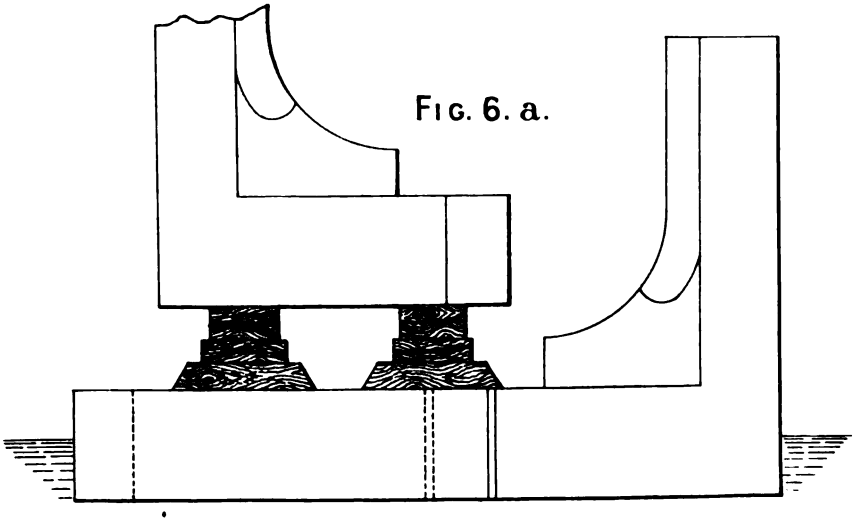
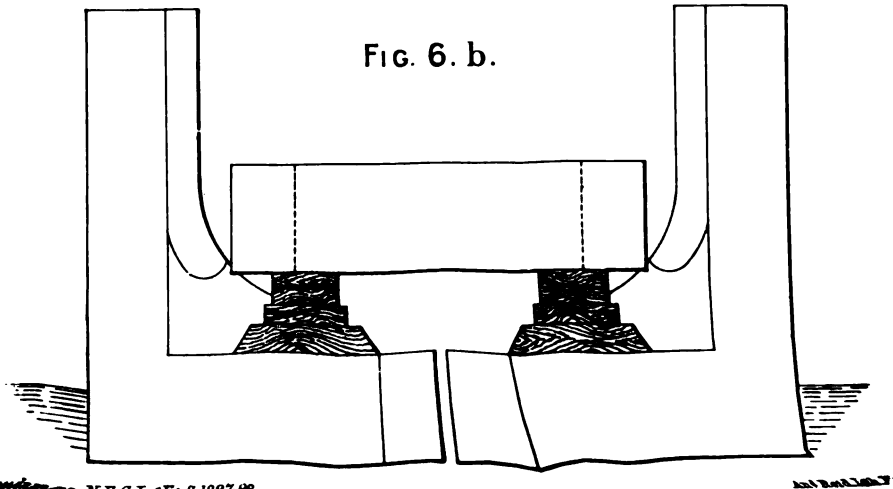


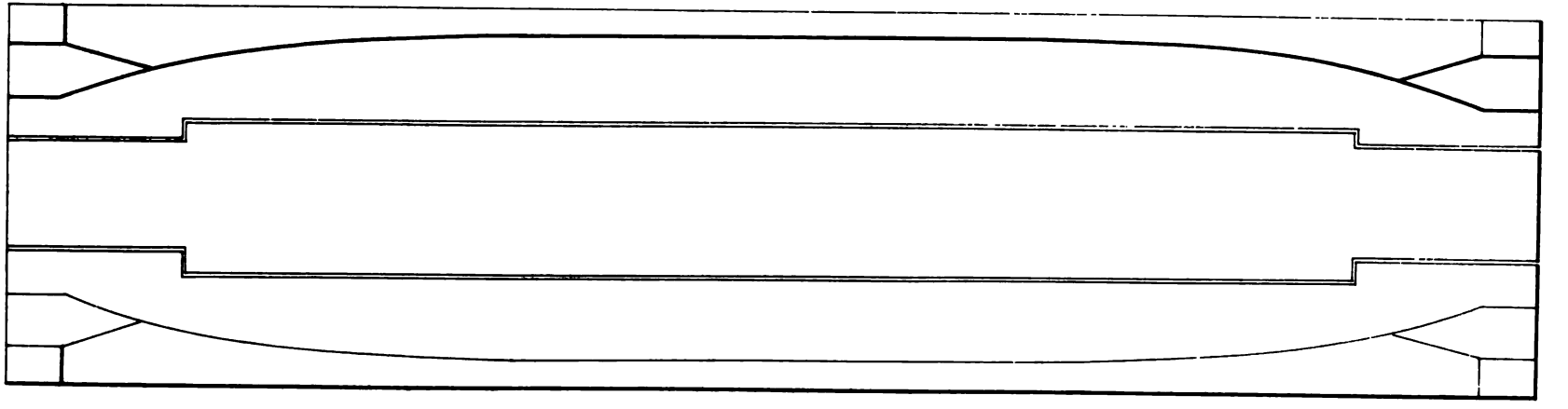
Fig. 6. b.



To illustrate Mr A. Taylors paper on "The Construction of Pontoon Dry Docks".

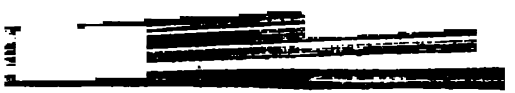
PLAN OF SELF DOCKING PONTOON DRY DOCK.

FIG. 7.



Scale $\frac{1}{8}$ Inch = 1 Foot

And Reid, Lith Newcastle



To illustrate Mr A. Taylors pa

FIG. 10.

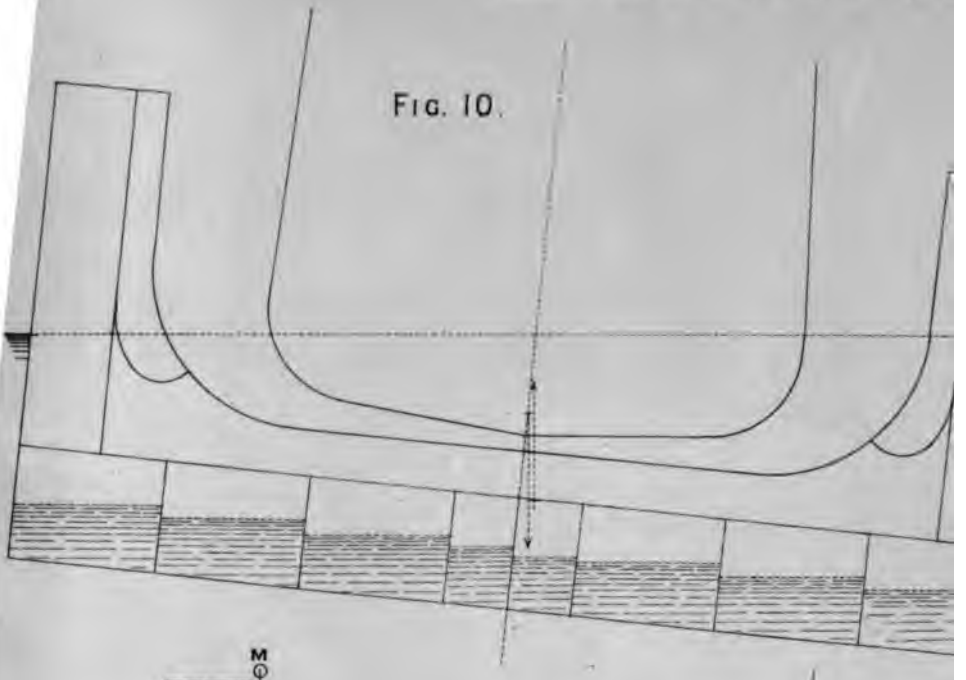


FIG.

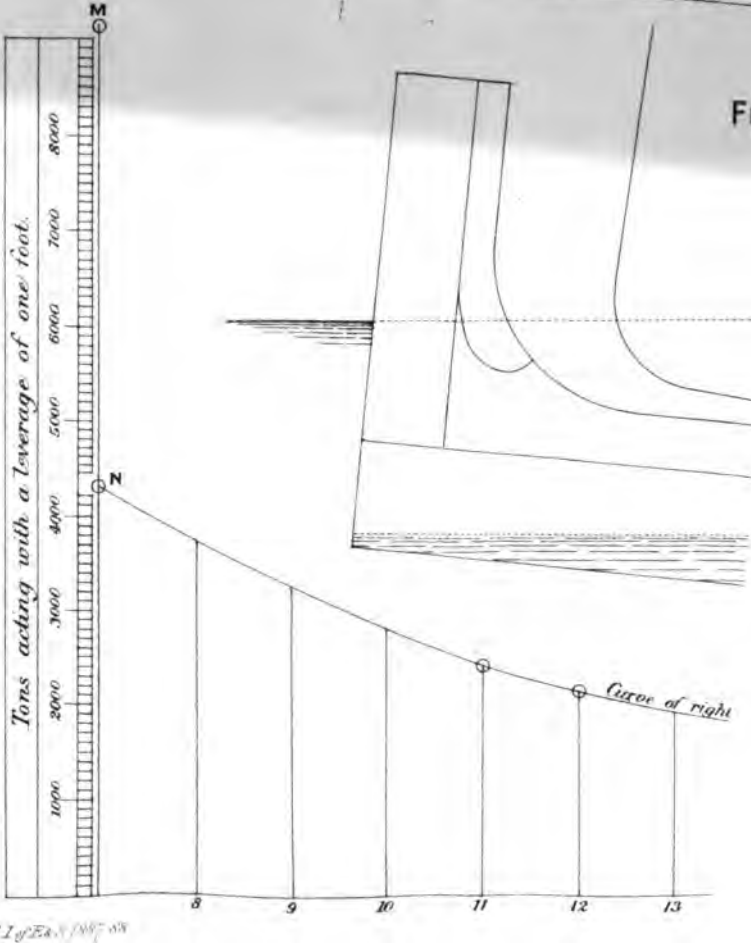
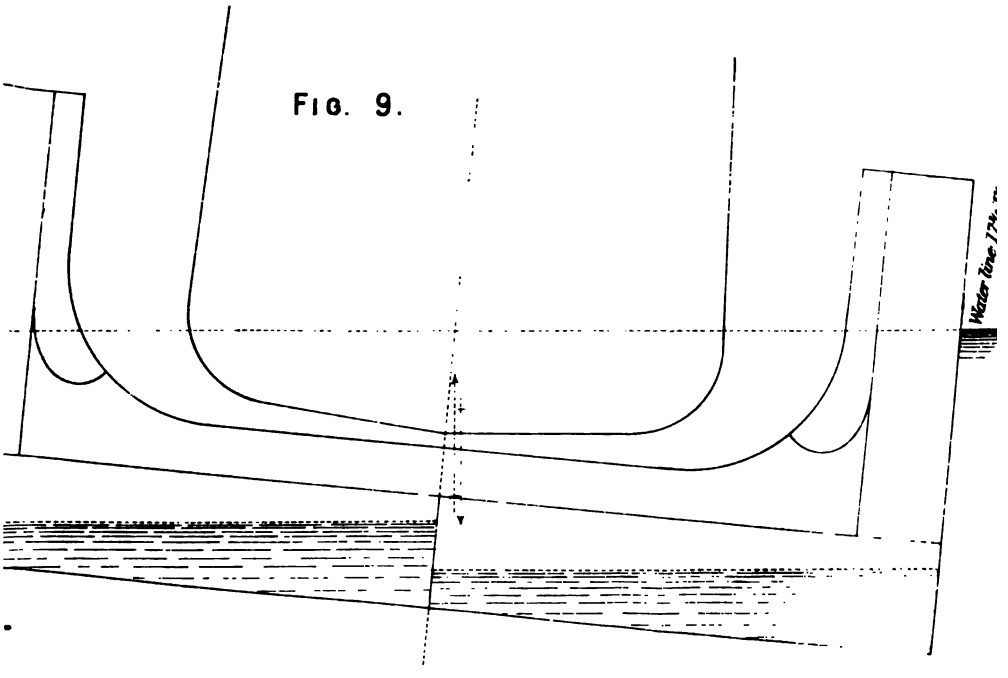
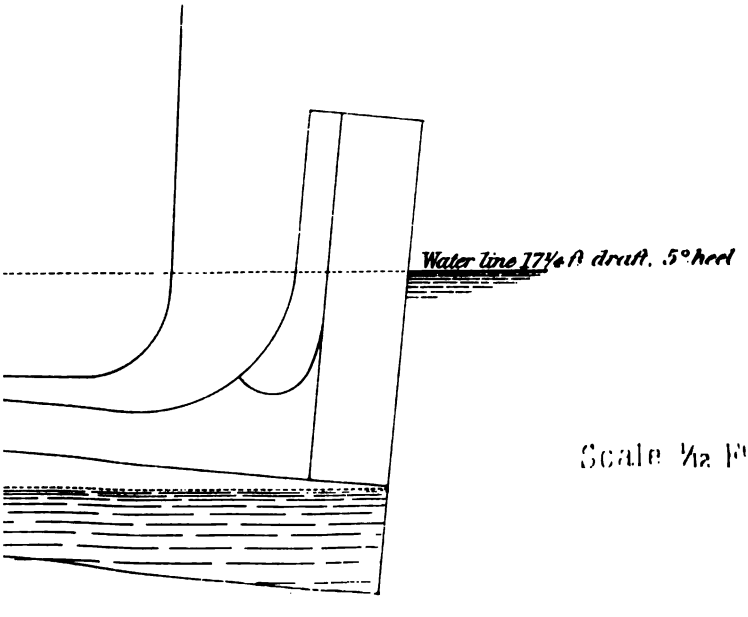


Fig. 9.





Scale ½ F. – one Foot

odel Pontoon, Fig. 10 at 5° heel.

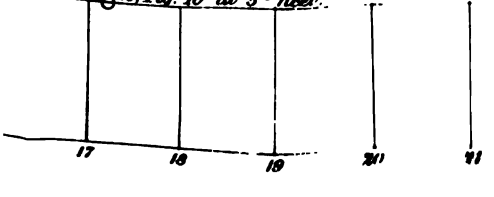
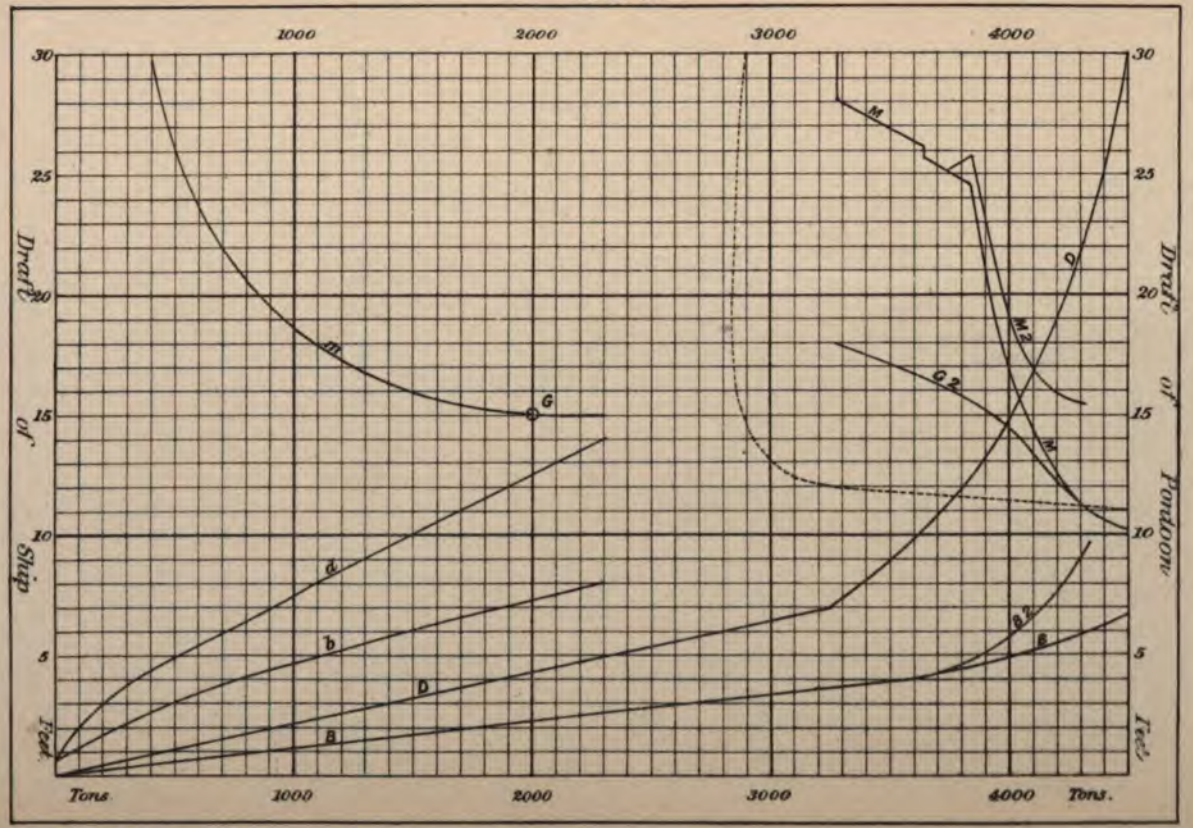


Fig 12.

To illustrate Mr. A. Taylors paper on "The Construction of Pontoon Dry Docks."

Stability Curves &c. for Model Pontoon Dock & Largest Ship.

Fig. II.



m Metacentric Curve of Ship.
d Displacement " "
b Centres of Buoyancy Curve of Ship.
M Metacentric Curve of Pontoon.
D Displacement " "
B Centres of Buoyancy Curve of Pontoon.
M2 Metacentric Curve of Pontoon and Ship combined.
B2 Centres of Buoyancy Curve " " "
G2 Centres of Gravity " " "

The Weight of Pontoon is taken as 1.250 Tons with its C.G. 6'5 Ft. above Bottom. The Ship as 2,000 Tons, with its C.G. 25·4 Ft. above Bottom of Pontoon, and the Ballast with its C.G. 3·5 Ft. above same

The Dotted Line shows position of Ship relative to Pontoon.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FOURTH SESSION, 1887-88.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, MAY 9TH, 1888.

W. THEODORE DOXFORD, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on April 11th, which were approved by the members present, and signed by the President.

The discussion on Mr. A. Taylor's paper "On Pontoon and Floating Docks" was then proceeded with.

This was followed by the closing business of the session.

DISCUSSION ON PONTOON AND FLOATING DOCKS.

Mr. WIGHAM RICHARDSON said, he had great pleasure in bearing testimony to the great value of the paper which his friend Mr. Taylor had contributed to the Transactions of this Institution. If the Transactions should consist in the future of many such papers, there would be no volumes more useful to the engineering public. The paper, as they would have seen and heard, was really a paper upon the construction of floating docks, and it had this great merit that it gave the working drawings and all the details in the construction of a dock, which had been since it was built in constant use very near to his own works, and in which he (Mr. Richardson) happened to be an investor, being a considerable shareholder in the company that had ordered the building of the dock; and he was very happy to say that from the first day it was started to the present time it had worked absolutely without a hitch. Sometimes some of them felt that papers were read at Institutes like this, in which somebody who had patented an invention gave them an *ex parte* statement, and if they inquired they found that the piece of machinery or engine described had not been very useful in practice; but this dock of Mr. Taylor's had been an entire and undoubted success. He believed that hardly any of the details had even been amended. One would have thought almost that Mr. Taylor had worked in the spirit of the old masters, who recognised that work must be perfect in every part, for the gods see everywhere! He believed himself that the principle of raising heavy weights by pumping out water from a vessel was likely to have still greater developments. He thought it was mentioned in Mr. Taylor's paper—at any rate he might draw their attention to the fact—that when a vessel of any given weight was lifted, say one of 3,000 tons, in order to lift that vessel they pumped out 3,000 tons of water, neither more nor less, whereas when a steamer was put into a graving dock, and Mr. Taylor had constructed a graving dock close to the pontoon, they had to pump the water from all round about it, and that water was very much more in quantity than the vessel itself; but

with the pontoon they had only to pump out water equal in weight to the ship. In foreign harbours, where they often had plenty of room and depth of water, he need hardly say that a pontoon dock of that description would be infinitely cheaper to construct, and more convenient, than the usual graving dock. In their colonies and dependencies, and at the so much talked about coaling stations, such constructions would be really invaluable. Of course, the principle of a floating dock was by no means new. It must be nearly a quarter of a century ago since Messrs. Rennie made the Bermuda floating dock; and other docks on the same principle, with various modifications, had since been sent from England to different parts of the world, and constructed in different parts of the world. Messrs. Mitchell—now Sir W. G. Armstrong, Mitchell, & Co.—had constructed docks for the Dutch settlement in Java. One was made on the principle of a series of cylinders (as it were a number of egg-ended boilers, forming a sort of raft), and he believed it was quite successful. But this dock of Mr. Taylor's seemed to him to have united really all the experience that had been gained over this long series of years. They had stiffness and convenience, safety, and a circulation of air for drying the paint, and the whole of the machinery connected with it was conveniently placed upon the structure itself. In conclusion, if any of his friends were desirous of building such a dock, he thought they would find that the paper they had under discussion would be an excellent reference for every detail of construction.

Mr. G. W. SIVEWRIGHT said, the paper read by Mr. Taylor was a very interesting one, and especially so to those members who were engaged in ship repairing. The large amount of work that had been done with the pontoon described must be gratifying to the company with which Mr. Taylor was connected. There could be no doubt that the pontoon form of dock had many advantages over graving docks. In the first place, the cost of building a pontoon was considerably less, and they could with some accuracy estimate what its cost of construction would be, but with a graving dock there was no certainty as to cost. There was another point in which a pontoon had the advantage, that was when they had a vessel to be docked with a strong list. Instead of having to "right" the steamer the pontoon could be partly canted over to suit the list of the vessel; but in putting a "cranky" vessel into a graving dock, the operation was often a very tedious and dangerous one to get her into an upright position. A pontoon could also be towed from one port to another, supposing the repairing trade was to fall off at any particular part of the coast; or even, as a last resource, it could be broken up and

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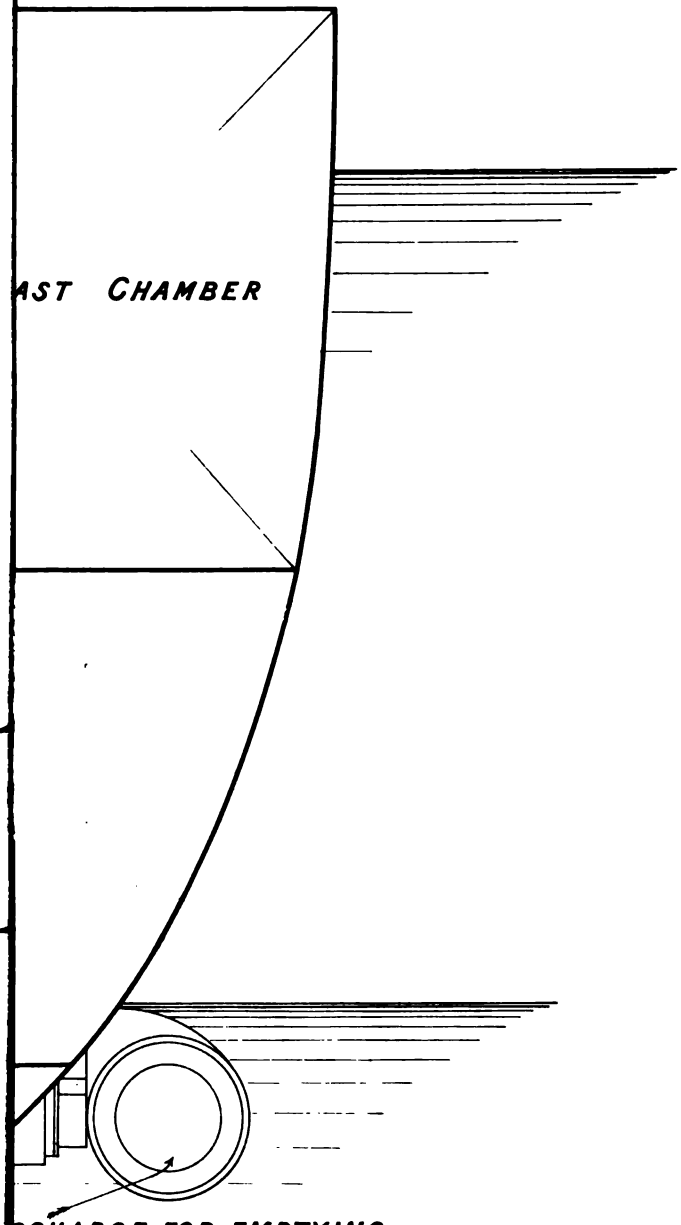


Ant Reid Lith Newcastle.

sold as scrap iron. From an examination of the plans of Mr. Taylor's design of pontoon, he could not see how it was possible to paint or repair the bottom if it got damaged, and he thought this was a very important matter for consideration. He remembered in designing a large floating dock some time ago the question of repairs to the bottom of the pontoon was seriously considered, and the conclusion arrived at was that it would be better to make the pontoon in cross sections of, say 100 feet lengths, so that portions of it could be beached and repaired; and even this arrangement was not the best that could be made. It appeared that Mr. Taylor had given this important point his consideration, as shown in the second design of the "self-docking" pontoon, and he thought if he had at the first been aware of the working success of the pontoon now in use, he would have spent a little more money and made the pontoon self-careening; but even in his second design of self-docking pontoon, a graving dock would be required to carry out the repairs. To make a floating dock perfect and economically worked, it should be constructed so that it could be repaired afloat. It would be quite possible to design a pontoon which could be repaired afloat with the bottom constructed, say of cylinders something like the floating hospital on this river; these cylinders could be taken out singly and repaired without having to dock the whole structure, but it would mean a larger structure, and of course more cost. Mr. Taylor had made several references to Mr. Rennie's paper on "Floating Docks," read in 1869. In the year 1883 Mr. Rennie took out a patent for a floating dock, which is illustrated on Plate XLVIII., and in his opinion it had all the points of a successful dock, for according to the arrangement of ballast chambers, it could be careened over to the centre line and repaired. This dock was something similar in the design of section to the Bermuda dock, and which they would remember, was towed out to its station. He was given to understand that the English Government intended to build a dock to this patent to repair their iron-clads abroad. Mr. Rennie stated in his specification that the centrifugal pumps would be powerful enough not only to empty the dock but to propel it by jet propulsion from port to port at a speed of something like four knots an hour.

Mr. H. Macoll considered the pontoon form of graving dock, as shown, was a very great improvement upon some of the structures for similar purposes made up of a combination of stone, concrete, and wood, which might be seen in the district, so long as there was room and depth of water available; the depth of water necessary being that required for the pontoon in addition to the depth of the vessel entering the dock.

The absence of provision for careening had been referred to by Mr. Sivewright, and the only other matter he wished to notice was the position of the boilers and pumps, although, no doubt, a very good place for the effective working of the latter; still, being so low down in the pontoon, in the event of any perforation taking place by damage it would be awkward to get at them to put them in order so as to clear the compartment of water and float the pontoon. It was well known what a serious matter it was when a dredger was damaged and became submerged to get the concern re-floated, and the position seemed to him to partake somewhat of the difficulties of the dredger. Otherwise he thought Mr. Taylor's pontoon dock a thoroughly good specimen of careful designing, and one that would prove satisfactory to all concerned.

Mr. D. ANDREW said, he could not let this occasion pass without mentioning what his experience in various parts of the world had been in the way of repairing steamers on floating docks. He had had steamers repaired in New York on what Mr. Sivewright called "sectional" docks, and he must say that the taking up of a steamer was a most unsatisfactory proceeding. As a rule, what he found in all sectional docks was that somehow they did not rise equally; there seemed to be nothing to guide the sections. One part sank, another rose on the opposite side, and made a most uneven lift. Then, with a current, they went rolling about like a ship in a seaway. On one occasion, putting a steamer on a floating dock with the engine room full of water, he (Mr. Andrew) was on board, and he felt very uneasy. There was a stiff gale of wind, and whenever the dock got a list he did not know when it was going to recover. In regard to cost he should say that the Carthagena dock was a very expensive one. In the first place it was expensive to build, and for the repairing of it they had had to make another dock—a dock built of stone; and one great mistake the Spaniards had made was that its depth being only eight or nine feet, it was of no practical use to take in a ship of any size, being only utilised for torpedo boats and such small craft belonging to governments. Certainly the dock referred to in the paper gave satisfaction in regard to its being a thoroughly safe dock, in its present position, but he should like to see it in open water, exposed to the full force of wind, and not tied up in a berth, sheltered on all sides; he did not know how it would then act: where it now was it did its work very well, and there was this advantage that in going on board the dock there was always a dry platform to walk on.

Mr. O. ULLSTROM having stated that Mr. Taylor had mentioned seven tanks, whereas the plans showed eight,

Mr. TAYLOR replied that the two centre tanks for convenience were numbered as one, but in the calculation they were treated separately.

Mr. ULLSTROM said, he had taken a great interest in Mr. Taylor's self-docking pontoon, which, he thought, was a very ingenious contrivance, and for many reasons preferable to the ordinary floating dock; but it seemed to him to have a rather weak point, viz., the athwartship strength, which almost entirely depended on movable bolts and connections. He thought it a rather serious affair if, with a large ship on the blocks, these bolts should give way and the dock collapse. He would take it as a special favour if Mr. Taylor could give them an idea of the comparative cost between that kind of dock and the ordinary one, and also the comparative cost between a dock to lift a ship of, say 1,500 tons weight, and one to lift a ship of about 3,000 tons weight. The tendency was towards bigger ships, and, therefore, it was rather important to know whether this type of dock (self-docking pontoon dock) would not turn out rather costly, on account of the increased connections athwartship, etc. Another important question was the maintenance of a floating dock; and any information with regard thereto that Mr. Taylor could impart would be received with thanks. He hoped Mr. Taylor would not think him too inquisitive in putting these questions to him, which were, perhaps, of a somewhat private nature. He, for one, begged to thank Mr. Taylor for his very valuable paper.

Mr. M. C. JAMES asked if Mr. Taylor could give them any information as to the longitudinal stability of the dock when submerged, a point to which Mr. Taylor had made no reference in his paper. It seemed to him that, were it not for the assistance given by the end towers, the dock in the submerged condition would be rather deficient in longitudinal stability.

Mr. TAYLOR, in reply to the discussion on his paper, thanked Mr. Wigham Richardson for his kind and flattering remarks, and agreed with him that this class of dock was the most suitable for the colonies.

Mr. Sivewright wished to know how the bottom of the pontoon (Plates XL. and XLI.) could be painted or repaired, and suggested it would have been better had it been made so as to be capable of being careened. In reply to this, he would say the Tyne Pontoons and Dry Docks Company, for whom this pontoon was built, have a very large graving dock which would easily admit the pontoon, hence it was not necessary to make this one either careenable or in sections. He would also say that for a long time he tried in every conceivable way to devise a plan by which this design of pontoon could be listed sufficiently to enable the

bottom to be painted, and gave it up as impracticable; for even calculating on certain tanks being filled, and 600 tons hung on the outside of the pontoon, its great stability would not permit of its being listed sufficiently to expose one-half of the bottom. Of course, in cases where it was impossible to dock the complete pontoon, then he agreed with Mr. Sivewright "that it should be constructed so that it could be repaired afloat;" and he further agreed with Messrs. Sivewright and Andrew, that a pontoon dock built in separate cross sections was not the best form of construction for this purpose. Plates XLIV. and XLV. show what he considered a most suitable design for a self-docking pontoon. This was designed by his assistant, Mr. T. Harrold; and if Mr. Sivewright examined it, he would see that it was perfectly self-docking, and did not require a graving dock to carry out any repairs that might be necessary.

Mr. Rennie's dock had many valuable properties, but it was necessarily comparatively bulky and heavy, and its form of cross section confined the ship, and gave a comparatively narrow working platform or deck, and little stability.

In answer to Mr. Macoll's objection to the position in which the pumps were placed, of course, there was no reason why the engine room should not have a double bottom, and then, if the outer plating was holed, the engine room would still be tight, and the pumps workable.

Mr. Andrew would like to see the pontoon "in open water exposed to the full force of the wind." Graving docks and slipways are usually placed in sheltered positions, but he would have no hesitation in sending this pontoon to sea.

Mr. Ullstrom asked for the comparative cost of ordinary graving and pontoon docks. It was impossible to give these costs unless all the local circumstances were known. So far as maintenance was concerned, this pontoon had been in constant operation for the past three years and had cost nothing except for painting. Mr. Ullstrom feared the self-docking pontoon connections would be difficult to arrange satisfactorily. He would assure Mr. Ullstrom that a simple and perfectly safe and satisfactory connection had been arranged, but it was not thought necessary to show these details here.

Mr. James asked for information as to the longitudinal stability when submerged. In the paper, on page 307, it was stated that, when the pontoon is submerged the centre of buoyancy is above the centre of gravity of the pontoon and its contained water, and is therefore stable; but, of course, as the pontoon is raised the combined centre of gravity is also raised, and the centre of buoyancy lowered, and its longitudinal

stability is provided for by the tanks being divided into four lengthwise. The pontoon had least longitudinal stability when it was lifted without a ship; when lifting a ship the longitudinal stability increased with the length of ship.

He was much obliged to them all for the kind way in which the paper had been received.

The PRESIDENT thought they would agree with him that Mr. Taylor's paper showed that he had very fully and carefully thought out all the details, both as to the stability and strength, the two essential points, of the pontoon dock. He had very great pleasure, indeed, in proposing a hearty vote of thanks to Mr. Taylor for his very able and interesting paper.

The vote was accorded with acclamation.

CLOSING BUSINESS.

The PRESIDENT said, now the discussion was closed, they would proceed with the concluding business of the session, and, to begin with it, he would ask Mr. Stirzaker to withdraw the resolution, notice of which was given at their last meeting.

Mr. STIRZAKER was pleased to comply with the request of the Council, and to withdraw the following resolution, viz.:—

"*That the members of this Institution realising the many advantages to be derived by a reading-room and library resolve that such shall be established in Newcastle-upon-Tyne, at an annual cost, not exceeding £150.*"

Further—"*That inasmuch as the income of the Institution is not sufficient to meet the additional expenses which will be incurred, and that the Junior Members and Graduates will probably be the most constant users of the reading-room, the necessary revenue shall be obtained by increasing the subscriptions of those members, namely, the 10s. 6d. subscription to be increased to £1 1s., and the 5s. subscription to 10s. 6d.; whilst only the preliminary cost of furnishing, bookbinding, etc., which will amount to about £150, shall be defrayed by the other Members and Associates of the Institution, each of whom shall be asked for a donation of £1 1s., or as much more as he may desire to contribute.*"

THE INCREASE OF SUBSCRIPTIONS.

The PRESIDENT submitted the following resolution as a substantive motion:—

"That as the annual cost of the Transactions combined with the general expenses of the Institution amounts to about one guinea per member, and as nearly 400 of the enrolled members subscribe only half-a-guinea and over 60 Graduates only five shillings per annum, it is found that the average receipts will not meet the annual expenditure; it is therefore necessary to increase the subscriptions of these two classes of members, the former to one guinea and the latter to half-a-guinea, in

which case it is hoped that a surplus may remain sufficient to enable the Institution to secure suitable offices, part of which may be used as a reading-room."

The matter, he said, was one that he felt to be of the utmost importance for the future success of this Institution. If they adopted the resolution, he was afraid that it would have the effect of reducing the number of those members now subscribing 10s. 6d.; but he felt sure that in a very short time their numbers would be more than made up. On the other hand, if they decided against this resolution, they would put their Council, and the Finance Committee especially, into a very awkward position. Explaining the substitution of the present motion for that intimated by Mr. Stirzaker, the President said that a considerable amount of dissatisfaction had arisen among members, especially those not residing in Newcastle, who objected to the raising of the subscriptions merely for the sake of a reading-room. Now, that was an entire misapprehension of the matter, and was probably occasioned by the way in which the Council first framed the resolution. It was absolutely necessary, as far as they could see, to increase the subscriptions whether they had a reading-room or not. The cost of the Transactions and the general expenses amounted upon an average to one guinea per member. According to that calculation, the present 10s. 6d. and 5s. subscriptions would leave a deficiency of over 200 guineas per annum—only, that they had a considerable number of members who paid two guineas; and this to a considerable extent balanced the loss, but not entirely. He appealed to his friends in Sunderland, and others non-resident in Newcastle, to take a broad view of the subject, and consider that it was for the benefit of the Institution as a whole to have its financial position made sound, and at the same time to have its own offices and reading-rooms for the use of its members. It was only in the event of there being a surplus that they would be at the expense of a reading-room, library, or general office. There was great need for such a place at present, as the copies of the proceedings of scientific institutions, both at home and abroad, were so crowded up at the Secretary's office as to be of little or no use to anyone.

Mr. F. C. MARSHALL, in seconding the motion, said it could not be sufficiently known to members the real necessity there was for their having some place to deposit their property; at present the Secretary's office was crowded out with the publications of various societies, contributed for the benefit of members of this Institution, but which were lying perfectly useless to everybody. If they had a room where these books could be referred to he thought it would be a very great advantage

to all the members. He was glad to see so many members from the Wear and Tees, and joined issue with the President in asking them to take a broad view of the proposal. The fact was that 400 of the 696 members were getting half-a-guinea presented to them every year for nothing, and the time was bound to come, and had come, when this free gift could be continued no longer. As a matter of common justice it was advisable that the contributions should be increased. He trusted that this would enable them to have sufficient means to get a local habitation such as their name deserved. Some one might say they had never shown any loss yet. True, they had not yet been on the wrong side with the balance ; but in a little time they would, for the contributions of the life members, sales of papers, and other irregular items had gone into the general fund, and these unreliable sources of income were not likely to increase so as to keep off a deficit. There was a difficult, albeit delicate, matter to which he should allude, and that was with regard to the gentlemen who did not see their way to pay their subscriptions at all. They paid the first contribution, received regularly the Transactions, but had forgotten to pay the second, third, and fourth subscriptions. He submitted that this course was scarcely creditable, and should be stopped as soon as possible, for he believed they had £30 or £40 arrears in this way —a good amount out of a total of £600. There were none, he was sure, who had any ambition to excel in their profession, who would grudge the cost of their valuable Transactions. Why, any "budding" shipbuilder could now construct a pontoon dock from the drawings supplied there that night. He did not see why they should lose a single member, and felt sure they would not.

Mr. D. Andrew, as a half-guinea subscriber, supported with pleasure the motion. He could not imagine their friends in the neighbouring ports of Sunderland and Hartlepool withdrawing their support because of the offices and reading-room being in Newcastle. The necessity of an office would be obvious to any one visiting their worthy Secretary's place. He would soon have to take his desk into the passage and leave his office at the mercy of the Institution and its works. He did not know but what they might have the 400 members classified, as some juniors might feel the pinch of having to pay a guinea.

Mr. W. Boyd said he felt that in discussing such an important topic he would like to have an opportunity of saying a word or two on the subject. Perhaps more than any other single individual he had had to do with the original discussions by which the subscriptions were fixed at 10s. 6d. for the ordinary members, and he wished to say

to-night, what he had taken several opportunities before of expressing, that it was to those members as a class and body more than to any other that this Institution owed its present existence. Therefore, speaking for himself individually, and not at all on behalf of the Council, he wished to say that, in assenting to any increase of those subscriptions, it was with very great difficulty and reluctance that he had brought himself to that position. The members must be aware that this matter of increase of subscription was not a matter of yesterday; it was before the Council in the time of his presidency, and has been before the Council on several occasions during the presidency of his friend Mr. Doxford, and the resolution now arrived at was the outcome of a long series of discussions at the Council meetings. He wished the junior members not to run away with the idea that this was an impulsive motion on the part of the Council to get more funds into the coffers of the Institution; it had only been arrived at after great difficulty and deliberation. Speaking for himself personally, he could not help admitting that the arguments used in opposition to the increase of the 10s. 6d. subscription were before the eyes of the members from the very beginning, namely, that although it was agreed that the 10s. 6d. subscription would not cover the average cost to each member, it was hoped that the cost of carrying on the Institution might be equalised, and the deficit made good by the extra sum derived from the two guinea subscriptions. When they first began, however, they set before them a standard very much lower than the standard to which they had subsequently attained. They never dreamt of such a volume of Transactions as would be published for the session now closing. It was never in the minds of the wildest imaginations that they should ever have such a collection of papers and expensive diagrams as was now before them; and it was therefore from that point of view, and that point of view alone, that he considered the Council justified in asking the 10s. 6d. members to agree to the increase in their subscription. That and one other thing: of course, it is very easy to be wise after the event. If the Council had selected a different term from "reading-room," and talked about a "reference library," perhaps it would have been more acceptable; but if any gentleman would take the trouble of going down to Mr. Duckitt's office on the Quayside and see our valuable Transactions and valuable contributions from other societies stowed away on the top of cupboards, he cared not whether it was called a reading-room or reference library, but he was confident such a visitor would consider it was for the dignity of the Institution that it should be in better quarters. He had no doubt what-

ever of the necessity for this change; at the same time he had come to it with some reluctance, and perhaps, as one of their oldest friends, the 10s. 6d. members will take it from him in that sense. He hoped the resolution would be carried with unanimity, because he should be very sorry indeed, and it would be very much to the detriment of the Institution, if this resolution should be carried in the teeth of a strong opposition. That was not what they wanted. Personally, he would rather see it not arrived at at all if not done willingly, heartily, and gladly, and on the broad ground that, whether members live in Sunderland, Hartlepool, or Jarrow, or wherever it be, it was for the good of the Institution as a whole. Some of them anxious for the prosperity of the Institution wished to see a very high level kept up, and this could only be done by the possession of a larger fund; and he hoped, as Mr. Doxford had said, members generally would take a broad view of the question, and join with the Council in the wish of keeping the Institution on the high level to which it had already attained.

Mr. A. PRINCE begged to move as an amendment—"That the subscriptions remain as at present." He thought it would be hard lines to debar young members, who were poorly paid, from the instruction found in this Institution by increasing their subscriptions. He was astonished no mention was made about increasing the subscription of the two guinea members, who would not feel an increase in their subscription so much as the juniors. It would be fairer to have a classification such as had been suggested by Mr. Andrew.

Mr. J. DYKES thought there should be three standards—first, second, and third. He knew several members of the Institution would leave if the subscriptions were raised. He did not speak for himself, but for others outside.

Mr. M. C. JAMES said he would second the amendment. His suggestion was for them to deal with this matter in another way. The Council, he thought, should endeavour to reduce the expenditure of the Institution. The diagrams accompanying the published papers, he considered, were got up in an unnecessarily lavish fashion, and occasionally some of the papers partook too much of the advertising character; and money might also be saved in postage by some cheaper method of communication with the members.

Mr. J. M. ALLAN deprecated reducing the standard of the papers or the published diagrams. The total cost of the Transactions last session had been £333. Perhaps that amount might have been reduced by asking for tenders from various lithographers. He considered the idea

of having three classes of members impracticable, but thought a subscription of 15s. all round would pay expenses.

Mr. H. MACOLL said, that not only had they obtained tenders for the Transactions, but they improved upon the lowest estimate, so that for better work they paid less money than at first. As for the postage, it taxed the Secretary's wits to get members acquainted with the working of the Institution, especially with the paying of their subscriptions, some having to be written to half-a-dozen times.

Mr. ALLAN, alluding to the cost of sending out the Transactions, said that it might be cheapened by giving them to a porter for delivery.

Mr. B. G. NICHOL observed that not only were the tenders carefully scanned and gone through, and the very lowest figure secured, but the various drawings were divided into classes, the price of the engraving depending upon its simplicity or otherwise. A committee was formed, and along with every paper the whole of the plates had been examined, classified, gone over, and settled with the printer before a single thing was put in hand. Members, he thought, might rest assured that so far as the cost of the Transactions were concerned, no trouble was spared to get them done as cheaply as possible, having regard to the quality of the work, and the maintenance of a standard equal to that of other associations.

Mr. ANDREW said, that in order to see how many of the younger members were not in a position to pay the 10s. 6d., they might call a meeting and send in a requisition to the Council, which might allow the signatories to remain at the old subscription. (A voice: "Too much of the 'inquiry note' in it.")

Mr. J. W. PACEY, referring to the amount for postage and Secretary's expenses, £71 7s. 10d, in the balance sheet of the previous session, said that parcels might be sent to all the members in one firm by train, or through the parcels delivery, and a considerable amount saved. The President had given figures to the effect, that deducting the amount of subscriptions of the ordinary members and graduates from liabilities, there would be a deficit of about 200 guineas, and that the subscriptions of the two guinea members would not make it up. He found the subscriptions of the two guinea members amounted to considerably over 200 guineas; they amounted to £294. He did not know how many two guinea members there were now——

The SECRETARY—The membership stands thus:—164 members at £2 2s.; 77 associates at £1 1s.; 397 members at 10s. 6d.; 62 graduates at 5s.

Mr. PACEY—There were, then, considerably more two guinea members this year. Again, he had been told that the members of the Literary and Philosophical Society had a right to come to all their meetings; they got a copy of their Transactions for the library, and he had heard it suggested that if the subscriptions were increased some members would withdraw and join the Philosophical, the subscription of which is £1 1s., and thus obtain the privileges of two Institutions instead of one for a single payment.

The SECRETARY explained that they had the use of the hall and rooms of the Literary and Philosophical Society free; they paid no rent, and were therefore obliged to allow their members to be present.

Mr. PACEY—Oh, certainly; I did not know that.

Mr. R. L. WEIGHTON remarked upon the fact that the various suggestions made by the members that night had all in turn been considered by the Council, and that mooted by Mr. Andrew, of instituting another class of membership, had seemed at first to them to offer a satisfactory solution of the difficulty. When, however, they went into it, and particularly when they considered the difficulty there already was in allotting the subscriptions between the three classes now in existence, they abandoned it as undesirable. He would ask the junior members to look at the matter in this way:—In order to meet the current expenses of the Transactions, one guinea per member was required. If therefore the junior members' subscriptions were raised to one guinea, the subscriptions of the senior members might be as a consequence reduced from two guineas to one guinea *if we decided to go on as at present without a library.* It is, however, not proposed to reduce the senior members below two guineas, and as it is estimated that the extra guinea these members pay will suffice to provide a library, it is very evident that the library will be paid for entirely by the senior members, and that nothing at all will be contributed towards its up-keep by the junior members.

The PRESIDENT, in closing the discussion, deprecated any attempt to reduce their expenditure at the expense of the Transactions. As to the postage, they should consider whether anything might be done by delivery in bulk, but feared that no appreciable saving could be made in this way. As to Mr. Pacey's statement about the deficiency being made up by the subscriptions of the two guinea members, he had calculated upon the full amount as a set off to the deficiency caused by the lower subscriptions, but the surplus was only one guinea per member, so leaving a deficiency of nearly 100 guineas. He should like to know whether Mr. Prince and his seconder wished the amendment to be put—they should like to be unanimous if possible.

Mr. PRINCE said he should rather have it put to the meeting.

On being put to the meeting, the amendment was largely outvoted.

The resolution, put to the meeting as a substantive motion, was adopted *nem. con.*

BYE-LAWS.

The PRESIDENT moved that the following alterations be made in the Constitution and Bye-Laws :—

CONSTITUTION.

"V.—Members shall be principals or principal managers engaged in engineering or shipbuilding ; civil, military, or mining engineering, or naval architects ; whose subscription shall be two guineas per annum : and other persons engaged in the above professions ; whose subscription shall be *one guinea* per annum."

"VII.—Graduates shall be persons under twenty-one years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscriptions shall be *half-a-guinea* per annum."

BYE-LAW 31.

Line 3, after "viz., one," insert *Past-President or* "Vice-President."

The proposals were agreed to.

MEETINGS IN HARTLEPOOL DISTRICT.

Mr. G. W. SIVEWRIGHT spoke of the possibility of increasing the membership of the Institution. He said there were a large number of gentlemen connected with shipbuilding and engineering in Hartlepool, Middlesbro', Stockton, and Whitby, and he was quite certain by holding the meetings as they did now only at Newcastle and Sunderland that they did not get as many of these gentlemen as they might do for members. Probably if the time of the meetings was altered to Saturday afternoon it might be some inducement to get gentlemen from these towns to the meetings, but at the time of evening that they were now held, any member coming from a distance had to stay all night in Newcastle, which was very awkward. The President had said it might be possible to have a summer meeting held at Hartlepool, Stockton, or Whitby, as the case might be, and he (Mr. Sivewright) thought that this was a very good idea, and was sure if it was carried out the owners of the different works in one or other of these places would be only too glad to show the members through their establishments ; and at the same time, if interesting

papers were read at these meetings, he thought it would cause gentlemen in these towns to take an interest in the Institution, and would lead to a considerable increase of membership. He thought this would be a very much better way to popularise the Institution, and to increase the revenue, than by attempting to cut down the postage and other minor expenses, or by reducing the very excellent diagrams and reports of their meetings.

Mr. R. THOMPSON thought Mr. Sivewright's remarks very much to the point. If something of the kind proposed were adopted it would be the means of spreading the interest in their Institution.

The PRESIDENT said it was the intention of the Council to take this matter into consideration during the new session and see what could be done in that direction. His own idea was that special meetings might be held, or a summer meeting. They could not very well have regular meetings in Hartlepool, but minor meetings might prove a great success.

ELECTION OF AUDITOR.

On the motion of Mr. MACOLL, seconded by Mr. CHARLTON, Mr. R. W. Sisson was re-elected Auditor.

WORK OF SPECIAL COMMITTEES.

The PRESIDENT said that almost from the commencement of the Institution, at any rate for the past few years, there had been two committees sitting, one on the horse-power question and the other on shipbuilding statistics. These committees had had an enormous amount of work to do, and were only now able to give in their reports. It was too late to bring them before the Institution as they should have been; but the Council had resolved to publish them in the Transactions for this session.* As regarded the Horse-Power Committee, they had had a very difficult and intricate subject to deal with, one which had been attempted by other institutions and people in influential positions, but who had entirely failed to come to a satisfactory result. The sub-committee who had had the matter in hand had stated it carefully and elaborately, and he hoped when they came to read the report that it would meet with their entire approval. Personally, he thought if their suggestions were not adopted by the world at large as the standard horse-power, at any rate they would form the basis of any standard afterwards adopted. The other committee had had an enormous amount of matter placed in its hands, and Mr. Macoll had written a report, with diagrams, showing in a very clear way

* *See* Appendix, page 333.

the progress of shipbuilding. He hoped that Mr. Weighton, who had drawn up the report of the Horse-Power Committee, and Mr. Macoll would be able during next session to read papers on the two subjects, so as to bring the matter more fully before the Institution.

Election of Officers.

The President declared the result of the ballot to fill up the vacancies in the Council for the ensuing year as follows:—

President—Mr. F. C. Marshall.
Vice-Presidents—Messrs. H. Macoll and R. L. Weighton.
Hon. Treasurer—Mr. B. G. Nichol.
Councilmen—Messrs. J. R. Fothergill, James Patterson, John Price, A. Scholefield (Associate), and R. S. White.

Installation of President.

The President said, it only now remained for him to retire from the chair, which he had occupied during the past two years, and hand over the position to his successor. He thanked the members of the Council who had assisted him so heartily during his term of office, and the Secretary (Mr. Duckitt) for his untiring energy and the willing assistance he had given him, being always ready to sacrifice his own time to oblige him. He thanked the Institution, as a whole, for the way in which they had always received him and overlooked all his shortcomings. He had great pleasure in welcoming Mr. Marshall to the chair.

The President-Elect (Mr. F. C. Marshall) thanked the meeting for the high honour he felt they had conferred upon him, in electing him to the presidency of the North-East Coast Institution of Engineers and Shipbuilders. They would have many opportunities, if he, in the order of Providence, was allowed to maintain this position, of hearing him during the next twelve months. He would ask their esteemed Past-President, Mr. Boyd, to move a resolution.

Mr. Boyd said, the duty now imposed upon him was an extremely agreeable one, and one that he had the pleasure of discharging twelve months ago. It was to propose a vote of thanks to the retiring President, Mr. Doxford. No one knew better than himself the labours of the office he had filled so ably during the past two years. He could speak from his own experience the feeling of relief which Mr. Doxford had experienced in vacating the chair. At the same time, he was quite sure Mr. Doxford, like himself, would always remember the honour which had been conferred upon him by being placed in the position of President of

this Institution. He would never regret the very great labours bestowed in the service of the Institution during that time. He had spoken of the support he received from the Council, but, on behalf of the Council, he should like to put the other side of the question, namely, that throughout the tenure of office, all the deliberations and discussions, all the divergent views of the members of Council, were always treated by Mr. Doxford with the utmost consideration; and he had, from his position in the chair, done his best to carry those discussions to a practical issue for the benefit of the Institution. He was quite sure the Institution was greatly indebted to him, and he hoped that that indebtedness was felt by the members present, and that they would join with him in a very hearty vote of thanks to Mr. Doxford for his services in the chair.

Mr. R. THOMPSON said he was very pleased to second this vote of thanks. During Mr. Doxford's tenure of office, as far as Sunderland was concerned, he had done everything he could to try and increase the membership of that district in the Institution. At the Council board he had, as Mr. Boyd said, always aimed at the Council arriving at the best results for the benefit of the Institution, and though he now vacated the chair he was sure he would still use his interest for its good and assist in carrying out any project of the Council which might be of advantage to the Institution or tend to increase its strength in the district. He deserved their hearty thanks for the way he had done it in the past, and, he might also say, for the further assistance they might expect in the future. He had great pleasure in seconding the vote of thanks.

The PRESIDENT (Mr. F. C. Marshall) accorded to Mr. Doxford the vote of thanks, which had been carried by acclamation.

Mr. DOXFORD said, he was fully repaid for any little trouble he might have been at during the past two years by the way in which the proposer and seconder had submitted the resolution and the hearty way in which they had responded. Mr. Boyd spoke of the honour of the position he (Mr. Doxford) had held. He looked upon it as a position which any gentleman belonging to the Institution might be proud to hold, and he thought it should be the ambition of everyone there to get into that position if possible. He now looked upon himself as having been put upon the shelf beside his friend Mr. Boyd; but neither himself nor Mr. Boyd were inclined to be shelved, for they intended to do whatever they could for the future of the Institution as much as they had in the past. He again thanked them.

Summer Trip to Forth Bridge.

The President said they had now closed the business of another year. He asked the co-operation of the Council and the members in the discharge of his presidential duties. It had been suggested that they should have meetings elsewhere than at Newcastle and Sunderland. The subject had already been under the consideration of the Council, and he pledged himself to its further consideration. He agreed that these peripatetic meetings had a beneficial effect upon the membership of such an Institution as theirs; and this, he thought, would be the result of having a meeting during the summer or autumn on the Tees. It was intended to have an expedition to the Forth bridge, and he was very pleased that this should take place at the beginning of his presidency. It was proposed that they should leave on Friday night, spend Saturday at the Forth bridge, and return either on the Saturday night or Monday, as gentlemen might feel disposed. The tickets would be available for these times; but of this they would have due notice in a circular issued to every member. In order to the success of the incoming year, need he say it was very essential that they should have good papers? and they would be glad to have notice of as many as possible during the next four or five months. He thanked them most heartily for the honourable position in which they had placed him.

The session then closed.

APPENDIX.

At a meeting of the Council, held on the 2nd of December, 1885, the two following sub-Committees were appointed, viz.:—

1.—The Engine and Boiler Power Committee.

"To investigate and endeavour to formulate a simple but comprehensive rule or measure of the Power of Marine Engines and Boilers, which, being in a measure scientifically sound and commercially convenient, shall be applicable to the various types and proportions which may obtain in practice."

The following gentlemen were elected members of this Committee:—

W. J. Clark (Chairman).

J. Brockat.	B. G. Nichol.
J. H. Irwin.	Alex. Taylor.
F. C. Marshall.	R. L. Weighton.

2.—The Shipbuilding Statistical Committee.

"To compile statistics and report upon the progress in Shipbuilding both in Great Britain and Foreign Countries during the last twenty-five years."

The following gentlemen were elected members of this Committee:—

J. Wigham Richardson (Chairman).

C. W. Hutchinson.	H. Macoll.
James Laing, Jun.	Ivan Mayor

H. F. Swan.

Each of these Committees had power to add to its number, and the Secretary of the Institution was appointed to act as Secretary to each.

1.—*The Engine and Boiler Power Committee.*—Shortly after the formation of this Committee, the Chairman (Mr. W. J. Clark) was obliged to retire on account of ill-health,* and another of its members, Mr. J. Brockat, was removed by death. Mr. W. Boyd, having consented to join the Committee, was appointed Chairman, and Mr. W. Kilvington was also elected a member by the Committee.

After holding many meetings, certain normal conditions were laid down and agreed to as a basis upon which to form a rule. Each member of the Committee was then requested to deduce his own particular formula, from such reliable data as he might possess or be able to obtain, and forward the results to the Secretary, by whom copies of each were placed in the hands of every member of the Committee. The whole were then thoroughly examined and discussed in concert, and from these several communications appropriate formulæ were worked out and agreed to. Mr. R. L. Weighton was appointed to draw up the Report embodying the decision of the Committee, and to submit the same to the Council for its approval.

This Report having been accepted and adopted by the Council, it is now appended to the Transactions, and it is hoped that the rule therein given may commend itself to the profession, and that its adoption may become general.

2.—*The Shipbuilding Statistical Committee.*—The principal work of this Committee was undertaken by the late Mr. Ivan Mavor. The Secretary placed himself in communication with the chief British consuls throughout the world, in order to obtain as far as possible reliable statistics. These were placed in Mr. Mavor's hands, who at once set to work to tabulate the information obtained; but in the midst of his labours, as is well known to the majority of the members of the Institution, he was suddenly cut off by a melancholy death. After his decease, Mr. H. Macoll took the matter in hands, and having submitted a Report, together with the diagrams annexed, for the approval of the Council, it was adopted, and is now added to the Appendix, in the belief that it may prove useful and interesting to many.

* Mr. W. J. Clark died shortly after his retirement.

REPORT OF THE COUNCIL ON THE HORSE POWER OF MARINE ENGINES.

In endeavouring to frame a general rule for Horse Power the Council has proceeded on the basis of *Indicated* Horse Power.

But it is evident that for any rule to be general in its application which involves indicated power, all engines must be assumed to conform to certain conditions, which conditions must be looked upon as normal, all other conditions being of course regarded as abnormal. Unless normal conditions be granted it is obviously impossible for any general rule to be formulated. The result given by the rule will therefore be called Normal Indicated Horse Power (N.I.H.P.)

With a view to presenting the matter in as clear a light as possible, the rule which the Council has decided to recommend will first be stated and defined; the conditions which have been assumed as normal to all engines of the class dealt with will next be given and explained by reference to the tables appended; and lastly the process by which the rule has been deduced in accordance with the above-mentioned conditions will be exhibited and explained step by step.

I.—The Rule.

Let D = diameter of low-pressure cylinder in inches.
(If there be more than one low-pressure cylinder, let D^2 = sum of the squares of the diameters.)

S = stroke of piston in inches.

P = working boiler pressure in lbs. per square inch above the atmosphere.

H = heating surface of boilers in square feet.

P*m* = mean-pressure in lbs. reduced to low-pressure cylinder.

R = revolutions per minute.

The following rule gives the maximum Normal Indicated Horse Power (N.I.H.P.), on loaded trial trip, of surface condensing marine Screw Engines working at any boiler pressure between 50 lbs. and 250 lbs. per square inch, under the conditions hereafter specified as "normal:"—

$$\text{N.I.H.P.} = \frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100}.$$

II.—Conditions assumed as Normal.

1.—That the steam, whatever may be its boiler pressure between 50 lbs. and 250 lbs. per square inch, is expanded by the engines to the same terminal pressure.

This condition is necessary for the purpose of arriving at the power of the engines by themselves, but it is modified in its application by the rule under certain circumstances when the boilers are taken along with the engines, as will be explained further on.

2.—That the expansion is effected by the engines with the same degree of efficiency for all pressures between 50 lbs. and 250 lbs. per square inch.

This condition secures that for the higher pressures, engines of triple, quadruple, or more expansions must be used, the number of expansions depending on the pressure.

As a result of Conditions 1 and 2 it follows that the mean-pressure reduced to the low-pressure cylinder (Pm) may be assumed as proportional to the cube root of the boiler pressure ($\sqrt[3]{P}$), and further that its actual loaded trial trip value may be taken without sensible error as $5{\cdot}6\sqrt[3]{P}$.

See Table I. (page 5) for proof of this.

3.—That the piston speeds of engines of different lengths of stroke are proportional to the cube root of their respective strokes; and, further, that the actual loaded trial trip value of piston speed may be taken as $144\sqrt[3]{S}$.

See Table II. (page 6) for the variation of piston speed with length of stroke under this condition.

4.—That in all cases where the engines and boilers bear to each other such proportions as to prevent Condition 1 from being fulfilled, without thereby violating Condition 3, the coal consumption per I.H.P. will not be affected, but will be constant for the same boiler pressure.

When the engines and boilers bear a certain proportion to each other, which proportion is indicated in equation (C) further on, Condition 1. in conjunction with Condition 2, secures that the coal consumption will be constant for the same boiler pressure.

But when the engines and boilers vary, in their relative proportions, from what is here called the normal proportion, it is necessary that Condition 1 should be departed from, if the coal consumption is to be preserved constant for the same pressure, and if Condition 3 is not to be violated. Table IV. (page 7) shows how nearly the rule fulfils this condition, with a variation of as much as 20 per cent. above and below the normal between the engines and boilers. This amount of variation may be expected to occur very seldom in practice.

5.—That the boilers are constructed in accordance with what will be generally recognised as the fair average practice of the present day in respect of the allowance of steam room in relation to power, the diameter, area, and pitch of the tubes, the relation of grate to heating surface, and the area of uptakes and funnel; that average natural chimney draught is used, or if forced draught be employed, that it does not exceed the average chimney draught; that the horse power is proportional to the heating surface (H) and to the cube root of the pressure ($\sqrt[3]{P}$); and, further, that the actual loaded trial trip horse power may be taken as $\frac{H\sqrt[3]{P}}{16}$.

See Table III. (page 7) for the allowance of heating surface under different boiler pressures.

6.—That the efficiency of the engine mechanism is constant, and that the propeller is such as to secure that the engines will utilise the boiler power referred to in Condition 5, in the manner prescribed in Conditions 3 and 4.

III.—Deduction of the Rule.

I.H.P. of engines $= \frac{\cdot7854\ D^2 \times Pm \times 2SR}{33000}$

" $= \frac{\cdot7854\ D^2 \times 5{\cdot}6\sqrt[3]{P} \times 144\sqrt[3]{S}}{33000}$ { Conditions 2 and 3, Tables I. and II. }

" $= \frac{D^2\sqrt[3]{PS}}{52}$ (A) (By reduction.)

I.H.P. of boilers $= \frac{H\sqrt[3]{P}}{16}$ (B) { Condition 5, Table III. }

From the above it is evident that A and B are equal,

i.e. $\frac{D^2\sqrt[3]{PS}}{52} = \frac{H\sqrt[3]{P}}{16}$

$\therefore$ $H = \frac{D^2\sqrt[3]{S}}{3{\cdot}25}$ (C)

Equation (C) expresses the normal relation between the engines and boilers referred to in the explanatory clause following Condition 4.

Assuming that the power of the engines and boilers when taken together will be equal to the mean of their separate powers, we have:—

I.H.P. of combined engines and boilers

$$= \frac{\frac{D^2\sqrt[3]{PS}}{52} + \frac{H\sqrt[3]{P}}{16}}{2}$$

$$= \frac{(D^2\sqrt[3]{S} + 3{\cdot}25H.)\sqrt[3]{P}}{104}$$ (By reduction.)

This expression may without sensible error, and for convenience, be written:—

$$\text{N.I.H.P.} = \frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100} \qquad \text{Q.E.D.}$$

NOTES.

1.—The only step in the above process of deduction which calls for further explanation is that by which the combined power of the engines and boilers is found by adding their separate powers and dividing by 2.

This step, though arbitrary, will be found to give results which very nearly conform to Condition 4, according to which condition the coal consumption per I.H.P. remains constant for any given pressure, even though the boilers vary from their usual proportion relatively to the engines.

Table IV. is, therefore, the justification for this step; and from this table it will be seen that the power given by the rule approximates very closely indeed *to the only power* which meets the proviso of a constant economy for a given working pressure, under varying relations of boilers to engines.

2.—For Paddle Engines the same rule may be used, with its coefficients modified to meet the altered condition of piston speed which usually obtains in these engines. Assuming, that under Condition 4, the piston speed of paddle engines may be taken at $90 \sqrt[3]{S}$, the rule may, without sensible error, be written:—

$$\text{N.I.H.P. of Paddle Engines} = \frac{(D^2 \sqrt[3]{S} + 5H) \sqrt[3]{P}}{160}$$

and Equation (C) would become: $H = \frac{D^2 \sqrt[3]{S}}{5{\cdot}2}$.

3.—The Council considers the term "Nominal Horse Power," as at present used, very indefinite and misleading as a measure of the power of marine machinery. If however, instead of *Indicated* power, a quantity be required which will compare more nearly with what is known as "Nominal Horse Power," the above rule may be used thus:—Nominal Horse Power $= \frac{\text{N.I.H.P.}}{6}$.

TABLE I.

SHOWING HOW THE MEAN-PRESSURE (P_m) REDUCED TO THE L.P. CYLINDER VARIES WITH $\sqrt[3]{P}$, AND THAT THE NORMAL P_m MAY BE ASSUMED EQUAL TO $5{\cdot}6\sqrt[3]{P}$.

Boiler Press. = P.	Absolute Press. $= P_1$.	$\frac{P_1}{15} = R.$	$\frac{1 + \text{H.Log.R}}{R} = C.$	$P_1C - 6 = M.$	$M \times {\cdot}663$ (P_m as calculated.)	$\sqrt[3]{P}.$	$5{\cdot}6\sqrt[3]{P}$ (P_m assuming it to vary as $\sqrt[3]{P}$.)	Error per Cent.
50	65	4·33	·569	30·985	20·543	3·684	20·630	+ ·421
60	75	5·	·522	33·150	21·978	3·915	21·924	— ·246
70	85	5·66	·483	35·055	23·241	4·121	23·077	— ·710
80	95	6·33	·449	36·655	24·302	4·309	24·130	— ·712
90	105	7·	·420	38·100	25·260	4·481	25·093	— ·665
100	115	7·66	·396	39·540	26·215	4·641	25·989	— ·869
110	125	8·33	·374	40·750	27·017	4·791	26·829	— ·700
120	135	9·	·355	41·925	27·793	4·932	27·619	— ·630
130	145	9·66	·338	43·010	28·515	5·065	28·364	— ·532
140	155	10·33	·322	43·910	29·112	5·192	29·075	— ·127
150	165	11·	·308	44·820	29·715	5·313	29·752	+ ·124
160	175	11·66	·296	45·800	30·365	5·429	30·402	+ ·121
170	185	12·33	·285	46·725	30·978	5·539	31·018	+ ·129
180	195	13·	·274	47·430	31·446	5·646	31·617	+ ·542
190	205	13·66	·264	48·120	31·903	5·749	32·194	+ ·904
200	215	14·33	·255	48·825	32·370	5·848	32·748	+1·154
210	225	15·	·247	49·575	32·868	5·944	33·286	+1·255
220	235	15·66	·239	50·165	33·259	6·036	33·801	+1·603
230	245	16·33	·232	50·840	33·706	6·127	34·311	+1·763
240	255	17·	·225	51·375	34·061	6·214	34·798	+2·118
250	265	17·66	·219	52·035	34·499	6·299	35·274	+2·197

TABLE II.

SHOWING THE PISTON SPEED AND REVOLUTIONS, ON THE ASSUMPTION THAT THE NORMAL PISTON SPEED IS EQUAL TO $144\sqrt[3]{S}$

S. Stroke in Inches.	$\sqrt[3]{S}$.	$144\sqrt[3]{S}$. Piston Speed in Feet per Min.	Revolutions per Minute.
16	2·52	363	136·12
18	2·62	377	125·66
21	2·76	397	113·42
24	2·88	415	103·75
27	3·00	432	96·
30	3·10	446	89·2
33	3·20	461	83·81
36	3·30	475	79·26
39	3·39	488	75·07
42	3·47	500	71·42
45	3·557	512	68·2
48	3·63	523	65·37
51	3·70	533	62·70
54	3·77	544	60·4
57	3·84	554	58·2
60	3·91	563	56·3
63	3·98	573	54·57
66	4·04	582	52·9
69	4·10	590	51·3
72	4·16	599	49·9
75	4·21	607	48·56
78	4·27	615	47·3
81	4·33	623	46·1
84	4·38	631	45·

TABLE III.

SHOWING HOW THE AMOUNT OF HEATING SURFACE PER NORMAL INDICATED HORSE POWER VARIES WITH THE BOILER PRESSURE, ON THE ASSUMPTION THAT THIS HORSE POWER EQUALS $\frac{H \sqrt[3]{P}}{16}$.

Boiler Pressure (P).	Square Feet of H.S. per Normal I.H.P. $\left(=\frac{16}{\sqrt[3]{P}}\right)$
50	4·34
70	3·88
90	3·57
110	3·339
130	3·159
150	3·011
170	2·888
190	2·783
210	2·691
230	2·611
250	2·54

TABLE IV.

SHOWING THAT THE HEATING SURFACE MAY BE VARIED TO THE EXTENT OF 20 PER CENT. ABOVE OR BELOW THE NORMAL AMOUNT, AND THAT EVEN UNDER SUCH CIRCUMSTANCES THE RULE GIVES THE HORSE POWER WHICH WILL BE OBTAINED IF THE COAL CONSUMPTION IS SENSIBLY CONSTANT FOR ANY GIVEN BOILER PRESSURE. $\left(\text{FOR ILLUSTRATION, ASSUME SCREW ENGINES } \frac{27''-43''-70''}{45''}\right)$

D.	S.	P.	H.	$\frac{D^2 \sqrt[3]{S} \sqrt[3]{P}}{52}$ Engines.	$\frac{H \sqrt[3]{P}}{16}$ Boilers.	$\frac{\text{Engines} + \text{Boilers}}{2}$	$\frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100}$ (N.I.H.P.)	Normal Piston Speed.	P_m.	Engine Efficiency.	Boiler Efficiency.	Total Efficiency or Coal Consumption.
70	45	150	$\frac{D^2 \sqrt[3]{S}}{3·25}$ = normal = 5363	1780	1780	1780	1780	512	29·81	100	100	100
70	45	150	20 % greater = 6435	1780	2135	1958	1950	512	32·66	96·7	105·9	101·3
70	45	150	20 % less = 4290	1780	1424	1602	1609	512	26·95	104·12	92·16	98·14

REPORT OF THE COUNCIL ON THE STATISTICS OF SHIPBUILDING DURING THE LAST TWENTY-FIVE YEARS.

THE Committee appointed by the Council some time since to "obtain Statistics of the comparative Progress of British and Foreign Shipping during the last twenty-five years," considered it desirable to submit to the Council the following Report, together with the Diagrams attached.

The Council has great pleasure in adopting this Report and placing it in the hands of the Institution.

The Committee regrets that a large proportion of the information obtained is of a somewhat fragmentary character, and will necessitate a considerable amount of further enquiries being made abroad to obtain anything like an adequate comparison, although it is somewhat doubtful whether it is practicable to obtain a complete and reliable account of shipbuilding in some foreign countries for any time beyond a recent date, as statistics appear to have received little attention. It is also intended to prepare comparisons of the tonnage lost and wrecked with that owned each respective year. For these records a considerable amount of information has been already procured, as will be seen from the Diagrams attached, and the Committee hopes to have the whole tabulated and laid before the Institution during the next session.

In the Diagrams already referred to, as the vertical lines represent years and the horizontal lines tonnage, they therefore explain themselves.

Diagram A, Plate XLIX., shows the total tonnage owned by the principal maritime countries.

Diagram B, Plate L., shows the steam tonnage owned by the principal maritime countries.

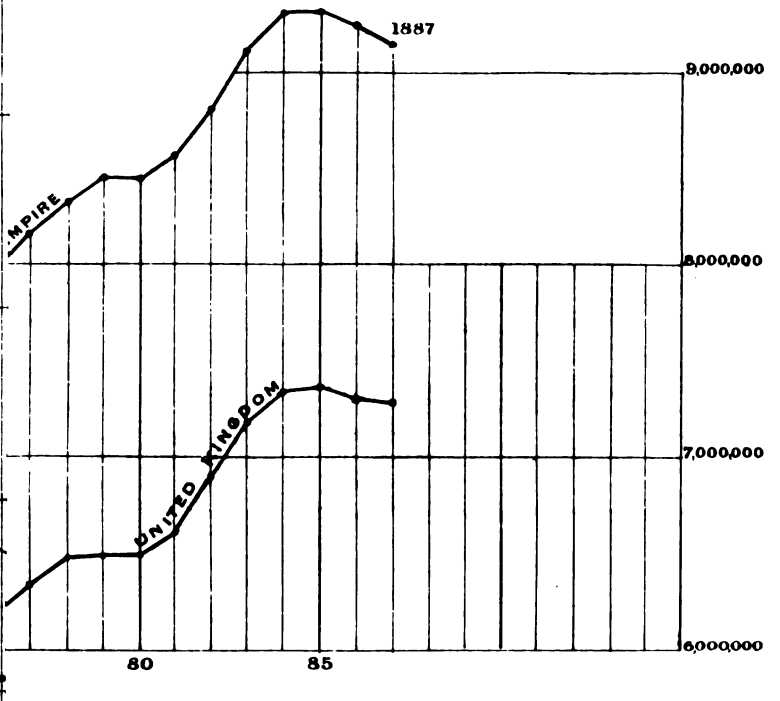
Diagram C, Plate LI., shows the tonnage built in the United Kingdom, also the steam and sailing ships separately.

Diagram D, Plate LII., shows the tonnage which has been added to the mercantile marine of the countries indicated in each year.

Diagram E, Plate LIII., shows the tonnage which has been built in the districts most largely employed in shipbuilding, and is subject to completion and revision.

It is to be understood that vessels employed in inland and lake service are not included.

On the question of statistics generally, it is gratifying to find that the United Kingdom still maintains its supremacy in shipping. At present the British mercantile marine is about 70 per cent. of the world's shipping; and as we possess a still greater proportion of the latest, fastest, and most improved descriptions of vessels, the carrying power of the British mercantile fleet is greater than that indicated by the actual difference in tonnage, notwithstanding the large bounties and other inducements offered to foreign shipowners and shipbuilders. On the other hand, a somewhat ominous reverse to the question is indicated by the diminished demand for British ships by foreigners. This fact, taken together with the rapidly increasing power of production by most, if not all, of the principal maritime powers, tends to show that all is not plain sailing for us in the immediate future; and care must be taken to indulge in no over-confidence in our superiority, or we may soon find ourselves, in addition to the almost over keen home competition, subjected to a very considerable foreign competition as well.



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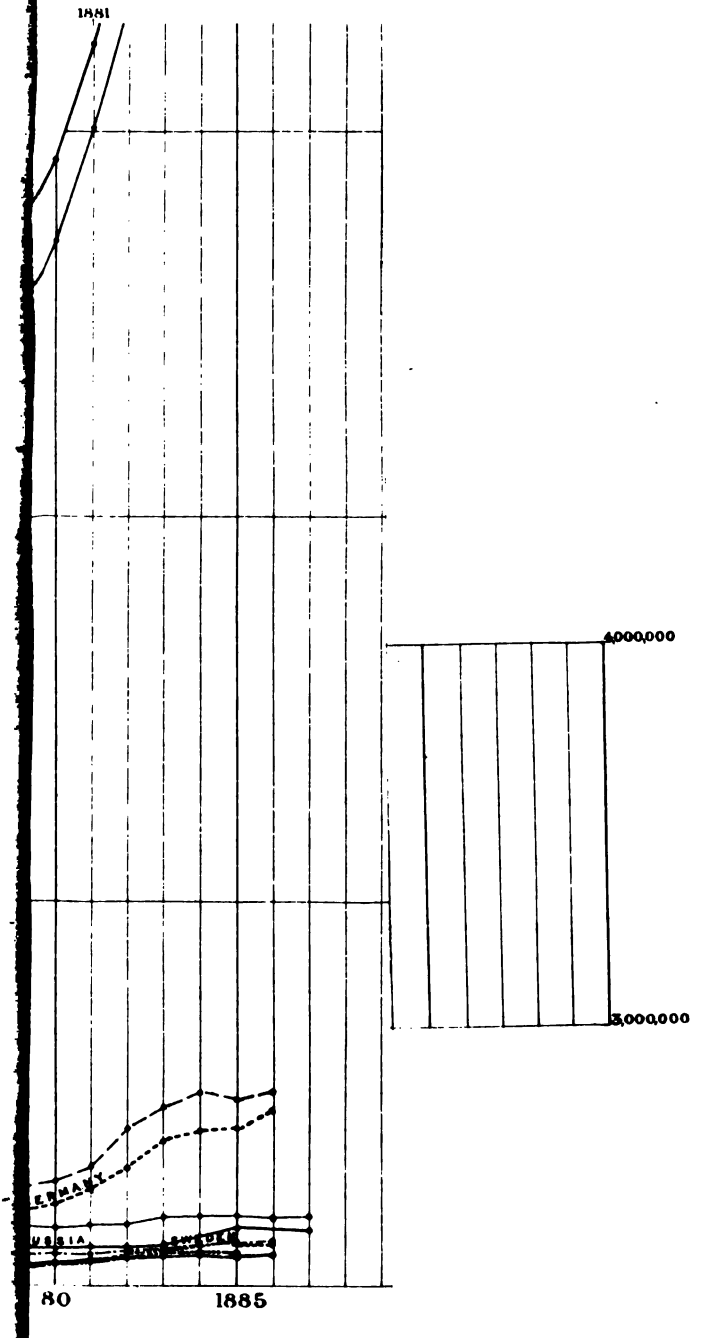

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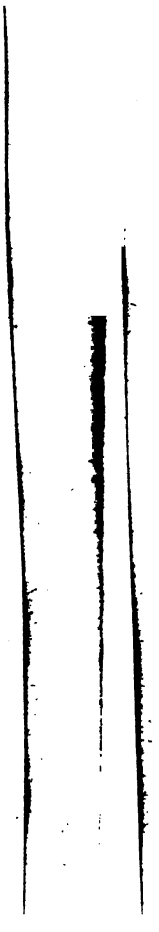

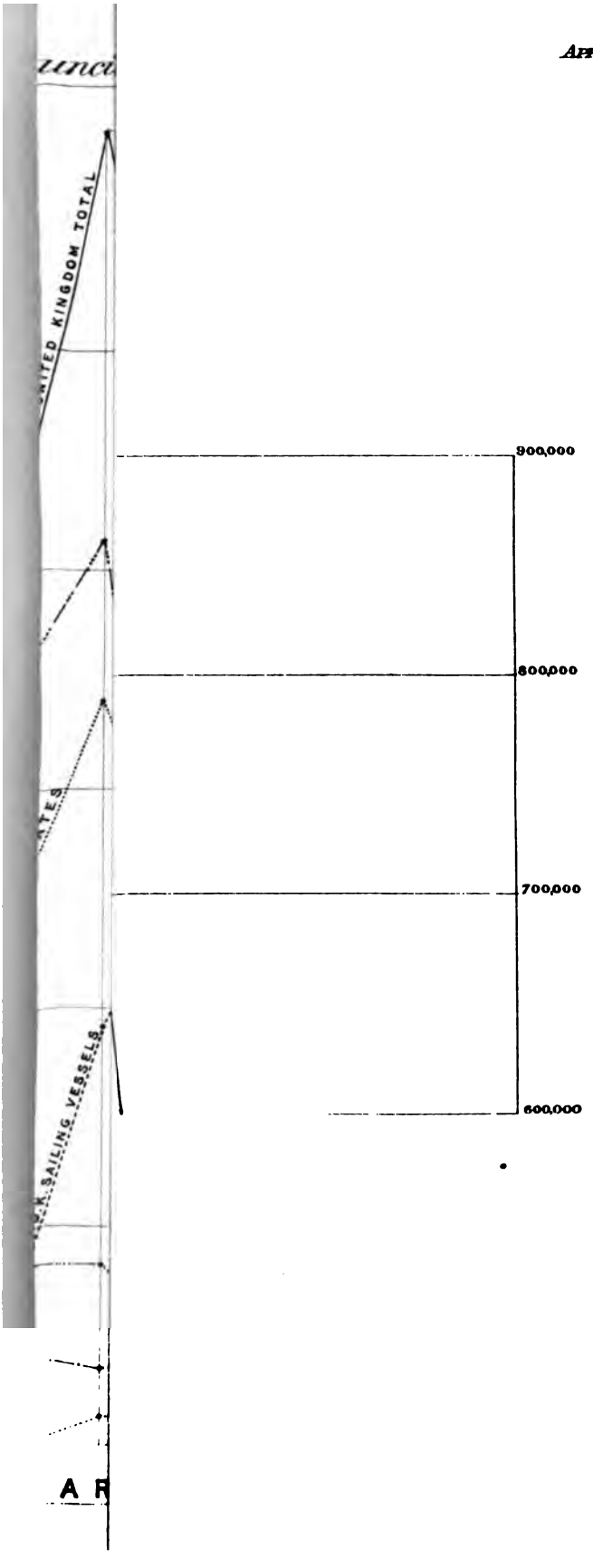

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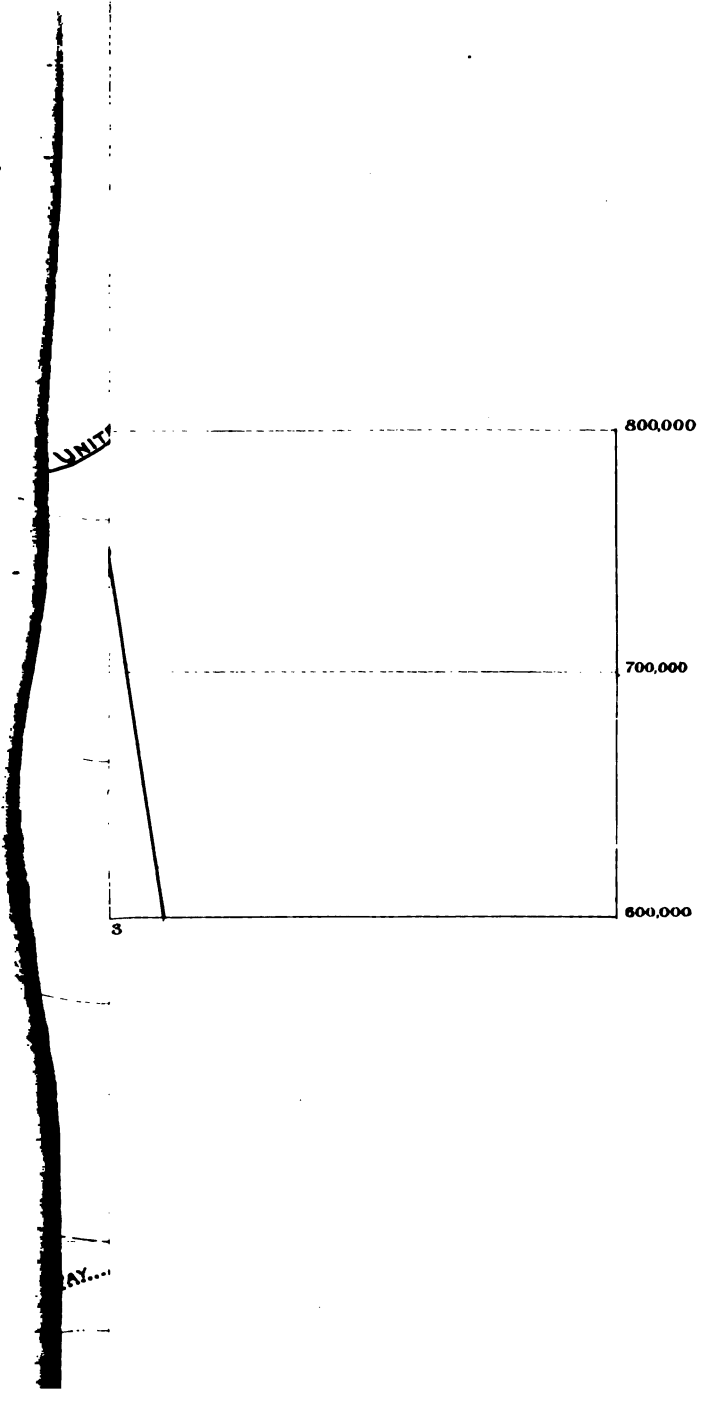

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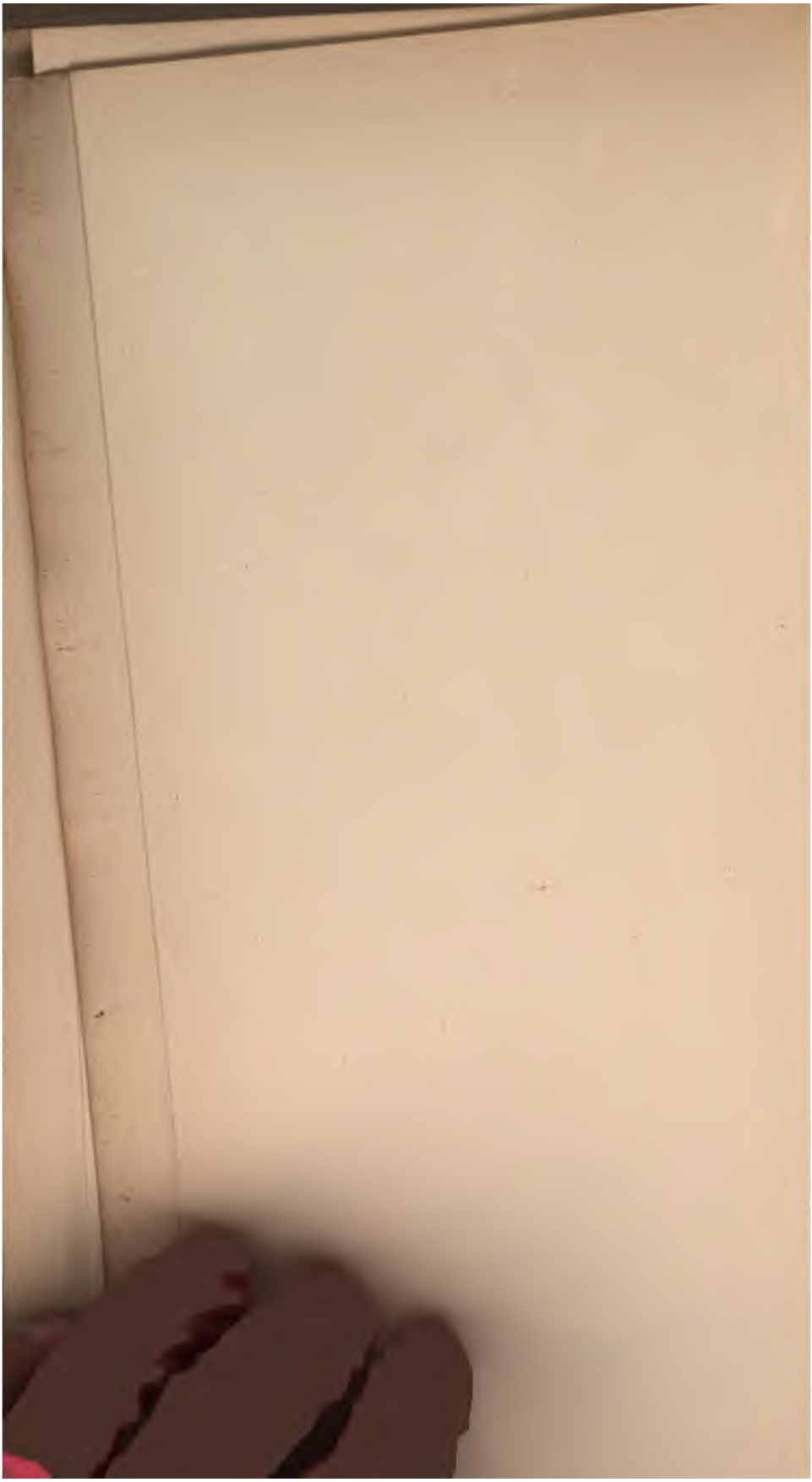

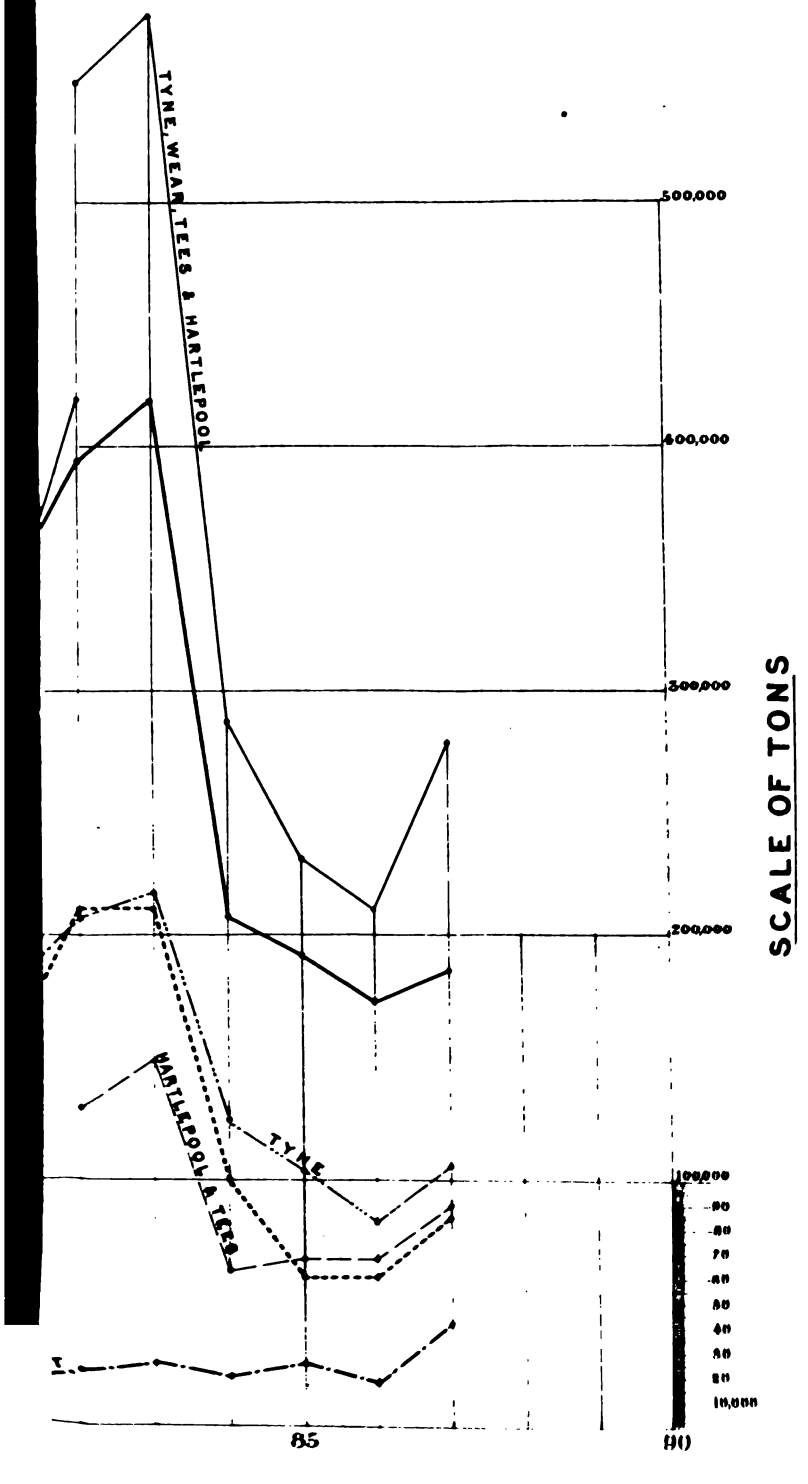

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